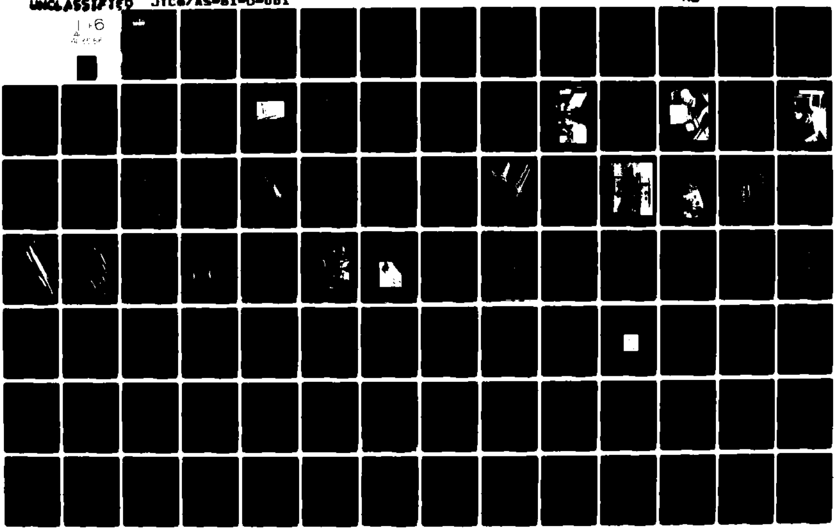
AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981

UNCLASSIFIED JTCG/AS-81-D-001 NL

1 of 6
AD
A113556



UNCL

ASSIFI

1 OF 6

AD A113556

JTCG/AS-81-D-001

FIELD OF INTEREST: 19.03

(1)

TCG/AS

AD A113556

PROCEEDINGS

A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DESIGN

SPONSORED BY
JOINT TECHNICAL COORDINATING GROUP
ON
AIRCRAFT SURVIVABILITY

APRIL 6-9, 1981
FT. WORTH, TEXAS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

THE FOURTH BIENNIAL AIRCRAFT SURVIVABILITY WORKSHOP ATTENDEES LIST

NAME	COMPANY ADDRESS	TELEPHONE
Aldridge, John R.	Naval Air Systems Command Washington, D. C. 20361 AIR 5184J4	202-692-1730
Arrighi, Joseph A.	Fairchild-Republic Conklin Avenue Farmingdale, NY 11735	516-531-2637
Avery, John G.	Boeing Military Airplane Advanced Airplane Branch P.O. Box 3707 MS41-10 Seattle, WA 98124	206-655-4373
Bailey, Kenneth W.	Naval Weapons Center China Lake, CA 93555	714-939-3327 or 3328
Ball, Robert E.	Naval Postgraduate School Monterey, CA 93940	408-646-2885
Berry, David C.	Naval Air Systems Command AIR-526X3 Washington, D. C. 20361	202-692-3490
Birken, John A.	NAVAIR, AIR-5181D Washington, D. C. 20361	202-692-3936
Bradburn, Paul	General Dynamics P.O. Box 748 Ft. Worth, TX 76101	817-732-4811 X5254
Byrne, Thomas J.	Falcon R&D 109 Inverness Drive East Englewood, Colorado	303-771-0818
Chan, Paul T.	Vought Corporation P.O. Box 225907 Dallas, TX 75265	214-266-4846
Coffield, Patrick C.	U.S. Air Force Armament Lab. AD/DLYD Eglin AFB, FL 32542	904-882-4688
Cox, Gary A.	Vought Corporation P. O. Box 225907 Dallas, TX 75265	330-4601(373)

NAME	COMPANY ADDRESS	TELEPHONE
Donnelly, J. Patrick	Boeing Vertol Company P. O. Box 15868 M/S P32-18 Philadelphia, PA 19142	215-522-3378
Dorr, Irene C.	Booz, Allen & Hamilton 4330 East West Highway Bethesda, MD 20014	301-951-2756
Frederick, Joseph M.	Air Force Aero Propulsion Laboratory AFWAL/POTA Wright Patterson AFB, 45433	255-2086/2367
Gomez, L. David	AFWAL/FIESD WPAFB, OH 45433	513-255-6031
Gray, Patrick M., Jr.	Vought Co. P.O. Box 225907 Dallas, TX 75265	
Hartung, John V.	Grumman Aerospace Main Station C27-05 Bethpage, N.Y. 11714	516-575-3721
Hoffner, James A.	Vought Co. Dallas, TX	214-266-5903
Hollingworth, M.B.	General Dynamics P.O. Box 748 Ft. Worth, TX 76101	817-732-4811 X3730
Horton, Richard A.	Naval Air Systems Command NAVAIR 5184J Washington, D. C. 20361	202-692-0230
Jackman, Dr. Gary R.	Lockheed-Georgia Company D/72-91, Z/415 86 South Cobb Drive Marietta, GA 30063	404-424-3077
Jackson, Keith, Jr.	General Dynamics P.O. Box 748 Ft. Worth, TX 76101	817-732-4811
Johnson, Kimber L.	Lockheed California Co. P. O. Box 551 Burbank, CA 91520	213-847-2230
Kelly, Larry G.	AFWAL/FIBC WPAFB, Ohio 45433	513-255-2582

NAME	COMPANY ADDRESS	TELEPHONE
Launders, Gordon A.	Vought Corp. P. O. Box 225907 Dallas, Texas 75265	214-266-5032
Liardon, Darrell L.	Bell Helicopter TEXTRON P. O. Box 482 Ft. Worth, TX 76101 (Department 81, Group 34)	817-280-3506 -2841
Lindsey, T. Joel	Lockheed-Georgia Co. Dept. 72-09, Zone 419 Marietta, GA 30063	404-424-4724
Lynch, Robert	General Dynamics P.O. Box 748 Ft. Worth, TX 76101	817-732-4811
Miller, Richard D.	Ballistics Research Laboratory Attn: DRDAR-BLV Aberdeen Proving Ground Maryland 21040	301-671-3551
Mitchell, Millard C.	Naval Air Dev. Center Code 2120 Warminster, PA 18974	215-441-2205
Moonan, Raymond L.	Rockwell International North American Aircraft Div. P.O. Box 92098 Los Angeles, CA 90009	213-647-3393
Morrow, John J.	Naval Weapons Center China Lake, CA 93555	714-446-5956
Nofrey, Bruce E.	Pacific Missile Test Center Point Mugu, California 93042 ATTN: Code 1245	805-982-7245 AV 351-7245
O'Connell, Donald L.	USAF CHIEF, ATTRITION Evaluation Br. 544S1W/D/A Offutt AFB, NE 68113	402-294-4666
Ozolins, Alvars	Ballistic Research Lab DRDAR-BLV Aberdeen Proving Ground Aberdeen, MD 21005	301-278-5534

NAME	COMPANY ADDRESS	TELEPHONE
Patrick, Larry, O.	Bell Helicopter TEXTRON P. O. Box 482 Fort Worth, Texas 76101 (Department 81, Group 34)	817-280-3506 -2841
Pearce, Daniel M.	Grumman Aerospace Corp. Bethpage, NY 11714 Mail Stop C35-05	516-575-3456
Potter, Myron	Douglas Aircraft Company McDonnell Douglas Corp. M.S. 35-95 3855 Lakewood Blvd. Long Beach, Calif. 90846	213-593-3203
Ricci, Richard	Lockheed California Company 2555 Hollywood Way P.O. Box 551 Plt. A-1 Bldg. 80 Dept 7011 Burbank, CA 91520	213-847-2196
Ridgeway, R.	Boeing Military Airplane Co. Advanced Airplane Branch P. O. Box 3707, MS41-10 Seattle, Washington 98124	
Ritter, Robert A.	Aero Engineering Division (Code601A) Naval Air Development Center Warminster, PA 18974	215-441-2288
Ruggiero, Rocco	Fairchild-Republic Conklin Avenue Farmingdale, NY 11735	516-531-3071
Saenger, Rudi F.	Naval Air Systems Command NAVAIR 526Z Washington, D. C. 20361	202-692-3443
Smith, David J.V.	H.T.L. Industries, Inc. Advanced Technology Div. 1800 Highlands Avenue Duarte, CA 91010	213-359-9317
Stein, Arthur	Falcon Research & Development Company One American Drive Buffalo, New York 14225	716-632-4932

NAME	COMPANY ADDRESS	TELEPHONE
Stephens, James D.	U.S. Army Research & Dev. Command 4300 Goodfellow Blvd. St. Louis, MO 63120	314-263-1634
Tuttle, Don E.	Lockheed-California Co. P. O. Box 551 Burbank, CA 91520	213-847-4812
Ullyatt, Lawrence G.	Falcon Research & Development Co. 109 Inverness Drive East Englewood, CO. 80112	303-771-0818
Vachris, Alfred	Grumman Aerospace M/S B17-035 Bethpage, N. Y. 11714	516-575-6337
Wallenberg, Robert	Syracuse Research Co. Merrill Lane University Heights Syracuse, NY 13210	315-425-5100
Wallick, Jerry D.	ASD/ENFTV Wright-Patterson AFB, OH 45433	513-255-6664
Watson, David J.	Armament Systems, Inc. 712-F North Valley St. Anaheim, CA 92801	714-635-1524
Weaver, Earl P.	ARMY Ballistic Research Lab. DRDAR-BLV Aberdeen Proving Ground Aberdeen, Md 21005	301-278-5432
Weir, Thomas J.	Conceptual Design/Northrop 3901 West Broadway Hawthorne, CA 90250	213-970-3873
Winterrowd, Clarence	General Dynamics P.O. Box 748 Ft. Worth, TX 76101	817-732-4811
Zust, Eric L.	McDonnell Aircraft Company P. O. Box 516 St. Louis, Missouri 63166	314-233-0745

JTCG/AS COMPUTER-AIDED DESIGN WORKSHOP
DISCUSSION TOPICS

At the conclusion of the computer-aided design workshop held in Ft. Worth, Texas from April 6-9, 1981, a roundtable discussion was held. Both Government and industry representatives participated, including:

Bob Ball, Naval Postgraduate School, Monterey, CA
Ken Bailey, Systems Survivability Branch, Naval Weapons Center, China Lake, CA
Richard Ricci, Automation Development Organization, Lockheed, CA
Joel Lindsey, Defense Design, Lockheed, GA
Tim Horton, JTCG/AS Center Office
Alvars Ozolins, Ballistics Research Laboratory, Aberdeen, MD
David Berry, Naval Air Systems Command
John Hartung, Grumman Aerospace
Bob Ritter, Aero Engineering Division, Naval Air Development Center, Warminster, PA
Al Vachris, RAIS Project Leader, Grumman Aerospace
John Aldridge, JTCG/AS Central Office
Tom Weir, Northrop Aircraft, CA
Larry Kelly, Flight Dynamics Laboratory Structural Division, WPAFB
Don Tuttle, Lockheed, CA
Darrell Liardon, Operation Analysis Group, Bell Helicopter
Dan Pierce, Grumman Aerospace
Millard Mitchell, Systems Analysis Division, Naval Air Development Center, Warminster, PA
Joe Arrighi, Fairchild-Republic
Pat Donnelly, Boeing Vertol
Jerry Wallick, AF Aeronautical Systems Division, Systems Engineering, WPAFB
Gordon Launders, Vought Corp.
Paul Chan, Vought Corp.
Ray Moonon, Rockwell/North American Aircraft Division
Gary Jackson, Lockheed, GA
David Watson, Armament Systems, Inc.
Pat Coffield, AFATL/DLYD, Eglin AFB
Earl Weaver, Vulnerability Analysis Division, Ballistics Research Laboratory, Aberdeen, MD
Clarence Winterrowd, General Dynamics, Ft. Worth, TX

The following pages are a summary of the roundtable discussion, as categorized by the seven discussion topics.

1. Near-term interaction/integration of SV with CAD/ICAD

The workshop participants agreed there is a definite near-term need for interaction and integration of survivability (SV) data with computer-aided design (CAD) and integrated CAD (ICAD) programs. A major JTCG/AS objective is to promote survivability as a design discipline and its integration into the design process. The most effective means for doing this should be to promote a successful integration of SV with CAD processes. It was felt, however, that the survivability community needed to draw the CAD community to it, not the other way around. The Design Criteria and Industry Interface (DCII) subgroup may provide the mechanism for doing this.

The survivability community, however, needs to be better informed about CAD/ICAD; be trained, understand it, and be able to use it. Conversely, designers employing CAD/ICAD need a greater knowledge of SV before survivability can become an integral part of CAD/ICAD design efforts. The ideal time for this integration to occur seems to be during the conceptual design phase. Basic survivability requirements are established during the concept phase based on preliminary cost benefit analyses. Frequently, this must be done on a very short term basis and the eventual achieved SV in the delivered system will depend largely on how well this is done There is no effective way to assess the value of various combinations of SV design features in so short a time, without the aid of CAD. Since there are plans to include SV modules in most CAD/ICAD programs that are on-line or are under development, the CAD/ICAD community will need a means to convert from conceptual geometry models to analytical models. Present survivability models, such as FASTGEN, are advanced design analysis tools and do not lend themselves to the conceptual design phase.

2. What can JTCG/AS provide industry to facilitate/expedite integration?

CAD Methodology

Industry needs the assistance of DOD in defining and developing CAD methods that are compatible with SV assessment techniques. Whether the method is for conceptual studies, preliminary design or full scale development it must permit determining SV design features, evaluating their effectiveness, and determining their costs in terms of weight, dollars and performance. Considering SV in the design of each piece or part will allow adding the sum of the parts to obtain a complete SV assessment.

It is at the conceptual design phase, not preliminary design, that SV modules could provide an initial SV assessment that may prevent costly design changes later. The trend is to design first for performance and consider SV an add-on. The reality is that SV is part of performance.

SV Design Requirements

The current trend is to include SV in new requirements documents so that it will be designed into the aircraft and not added on at a later date. The A-10 is an example of SV being included from the beginning.

The F-18 and the V/STOL were cited as examples of survivability add-ons. The consensus was that the CAD/ICAD community needs to be educated on the importance of SV, and the emphasis should come from DOD as well as the JTCG/AS. If this is done, then computer-aided design and SV can be integrated sooner.

Historically, however, there haven't been definite SV requirements in the early stages of conceptual design. Conceptual designers cooperated with operational analysts and system analysts, and although survivability was inherent in some designs, it only occasionally seemed to be significant enough to affect the total design. (Exceptions are the A-10, H-60 and H-64.) An airplane was evaluated on such factors as performance, weight, and fuel consumption but not on its SV criteria.

The specifications and standards sponsored by the JTCG/AS Central Office require SV in all acquisitions or major MOD programs. These requirements show up in RFPs as well as RFIs and detail specifications. The problems that arise in complying with the requirements fall into two categories: 1) convincing industry that the Services are serious about survivability and 2) integrating the classified specification requirements into the guidance provided to designers.

In convincing industry that Government is serious about SV, it was suggested that documentation be more specific. If SV is not required through the specification, no one will pay attention to it. If the requirements are too specific, however, they may limit the designer and possibly cause excessive cost and weight penalties. Industry would be more responsive, especially to RFPs, if financial incentives were added. If RFPs/RFIs include extra rating points for increased survivability or

if flyoff competitions were held more regularly, such as in UTTAS, it would ensure that SV and CAD are included in the overall design.

Becoming familiar with survivability often involves a better understanding of the threat and threat scenarios, since aircraft design is driven by the threat scenario. Consequently, integrating SV with CAD will be somewhat influenced by availability of classified data. This is especially true for requirements for radar cross section. If the need-to-know is well established, however, the data is obtainable in classified reports, especially those distributed by JTCG/AS. It is the responsibility of the Government to ensure that documents referenced in RFPs/ RFIs or in specifications are made available to industry. Where limited distribution documents are involved (U.S. Government only-T&E etc.), it is very helpful if the procuring agency provides a bidders' package containing all the required documents, computer programs, or methodology.

The problem of communicating SV requirements should be alleviated soon. MIL-STD-2069, Requirements for Aircraft NonNuclear Survivability Program, is now available. It is a general specification for use in conjunction with the aircraft detail specification in tailoring SV requirements for each specific aircraft. Aircraft detail specifications, such as the Army's MIL-STD-490 style Prime Item Development Specifications, the Navy's soon to be published SD24L, and the Air Force's forthcoming MIL-PRIME Specs, all address SV requirements in unequivocal detail. Particularly important though is that MIL-STD-2069, on which the aircraft detail specification is based, is only written after a careful conceptual phase has examined the costs and benefits of various levels of survivability design, and "sold" the program to Service Chiefs and Congress.

Conceptual CAD-Government/Industry Interface To Establish and "Sell" SV Design

CAD, with SV analysis and cost benefit capability, will make it possible to examine various levels of SV design of single aircraft, and various combinations of proposed aircraft of varying configurations. It will help determine the best way to perform the service mission, optimized by any combinations of specified parameters (e.g., performance, size, weight, cost, mix of aircraft, etc.). It will permit doing this fairly accurately, within the often extreme time limitations imposed by the needs of Service Headquarters, Service Secretaries, OSD and Congress. The political and economic reality of the

80's will be that only those programs with credible designs and credible cost predictions will be funded. For SV features to be included in any new or service life extension design, CAD must be able to show the costs in terms of weight and dollars and the benefit of each SV design requirement.

3. <u>Definition of a "common data base"</u>

Government and industry should define a common data base, which will be very difficult because they are separate, isolated groups. Since a three-dimensional data base seems to be necessary, this may be accomplished by defining vulnerable areas, by using the geometry of basic components, and through using $P_{k/h}$. Another viable data source would be a library on $P_{k/h}$, scenarios, threats, components, engines, etc. This could help establish a whole network of capabilities that could blend to define the configuration of such items as components and systems. Communicating the configuration without interpretation is necessary, which would mean topology.

Once SV is entered in the conceptual design phase, then the survivability community could establish a simple model to use in that phase. In this manner, a simple library could be built, and the vulnerability specialist could move the components around the airplane and do the analysis. The model could be a simplified tool for conceptual design and cost analysis, and could provide inputs to other more sophisticated programs as a long-term goal as well.

The JTCG/AS bibliography could also be used in setting up a common data base. By reformatting the indexing system with the subject codes, users could search for data items by subject and not merely through the report documentation titles.

4. <u>Who else needs to be involved?</u>

The aircraft designer needs the survivability engineer to tell him how to arrange the components in the airplane for improved survivability, whether it be from ground fire, IR missiles, etc. A SV engineer needs a simple model to assess the design that the configurators come up with. The computer graphics system will help refine that model or tool so as to differentiate between separation and redundancy. Thus, the SV engineers can put in any SV features overlooked by the airplane designer.

Because propulsion engineers have a large investment in CAD, they should be included in future workshops and meetings.

5. How well defined is the CAD community?

The computer-aided design community is fairly well defined. AIAA has a new CAD/ICAD subgroup. There are CAD organizations from the university to corporate level. The IEEE addresses the CAD community through its user's group. The aircraft designers, however, are integrated with the automotive designers.

6. Coordination/standardization/development objectives

Coordination

JTCG/AS hopes to publish a security guide addressing basic SV data. As an interim guide, the Navy Survivability Classification Guide is available through the JTCG/AS Central Office. Essentially, the design requirements and the effects of munitions against airframes will not be classified higher than Confidential.

Better coordinated documentation will help the liaison at the working levels with the JTCG's. This is true in vulnerable areas, especially in vulnerability assessment techniques.

Standardization and Development

Better coordination will hopefully lead to a standardization of susceptibility models, which is needed. The models should be simple, if possible, and geared first for use with radar cross sections, IR, countermeasures, and camouflage.

Because CAD can be of help with its inherent capability to change ideas quickly, JTCG/AS should look at developing more simplistic tools. These tools can be used in the conceptual design phase. For example, with a library of $P_{k/h}$'s at CDIC for use in the conceptual and preliminary design phases, a designer can do an assessment and redo it quickly if it's found to be inaccessible or unsuitable. In this manner, the designer can accomplish rapid, progressive survivability assessments as they work through the conceptual design. The question remains, however, of who should actually develop the tools and the formats.

7. Future workshops

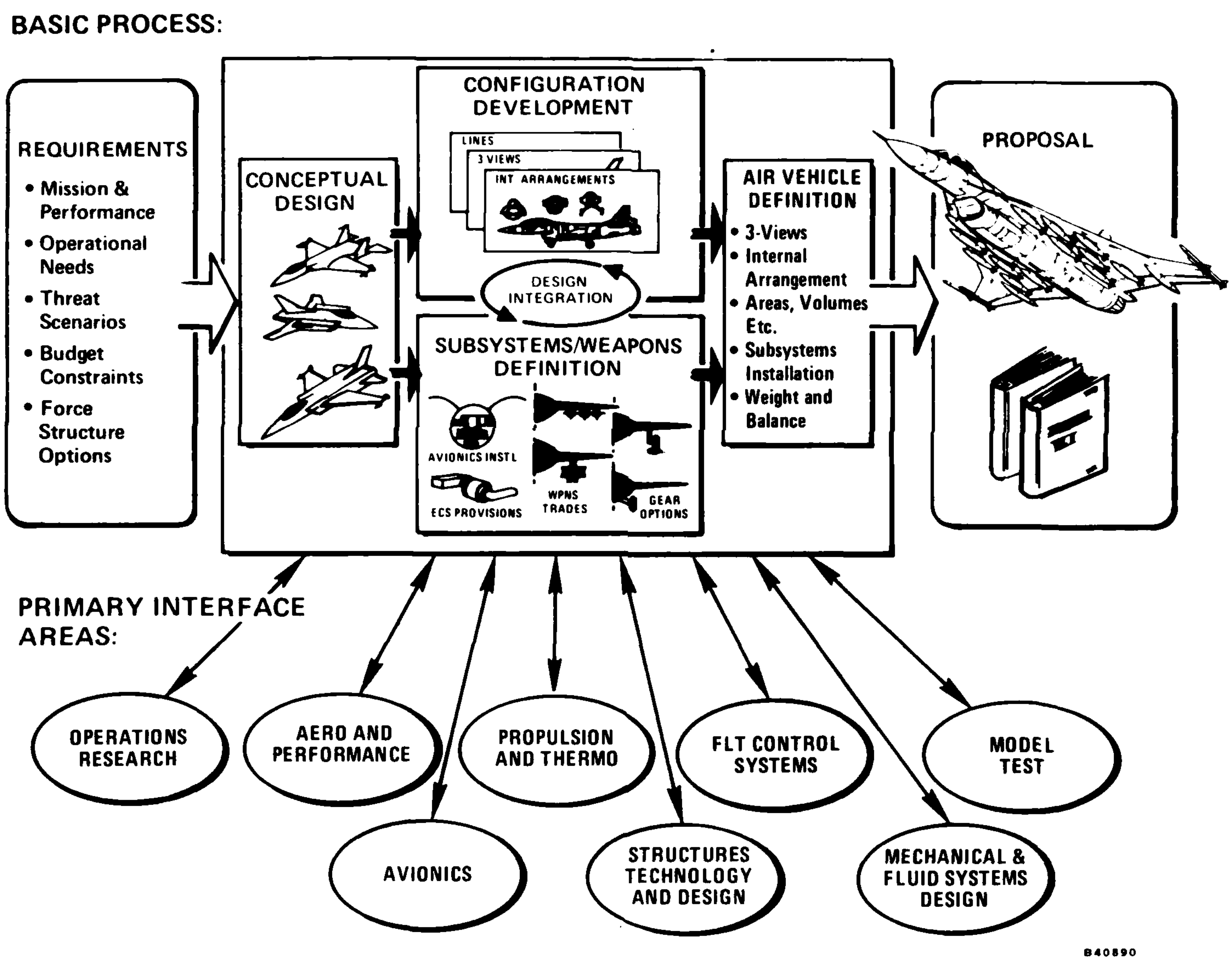
Yes, future CAD workshops would be beneficial, although separate workshops for special interest groups also might be feasible. The next session should address threat, the CAD/ICAD/CAM ability to address threat, and the types of damage caused by the threat. The designers should integrate these areas with any analysis that is done in order to evaluate the capabilities of the aircraft. JTCG/AS could then publish the collective results of the analysis.

If a workshop is held again in a year, possible locations could be Wright-Patterson AFB, OH where the CDIC is located or the Naval Weapons Center in California.

THE ADVANCED DESIGN PROCESS

Robert W. Lynch
General Dynamics
Ft. Worth, Texas

THE ADVANCED DESIGN PROCESS



ADVANCED DESIGN PROBLEM

- HAND METHODS CAN'T KEEP PACE WITH WORK VOLUME
  - THREE VIEWS
  - INBOARD PROFILES
  - CONFIGURATION LAYOUTS
  - WIND TUNNEL MODEL LINES
  - VOLUME MEASUREMENT
  - AREA CURVES
  - PERSPECTIVE DRAWINGS
  - CLEARANCE STUDIES
  - LANDING GEAR MOTIONS
  - PILOT & SENSOR OBSCURATION DIAGRAMS
  - WEIGHT AND BALANCE
- CONTINUAL "SHORT FUSE" OPERATIONS REQUIRE "QUICK RESPONSE" CAPABILITY

OBJECTIVES

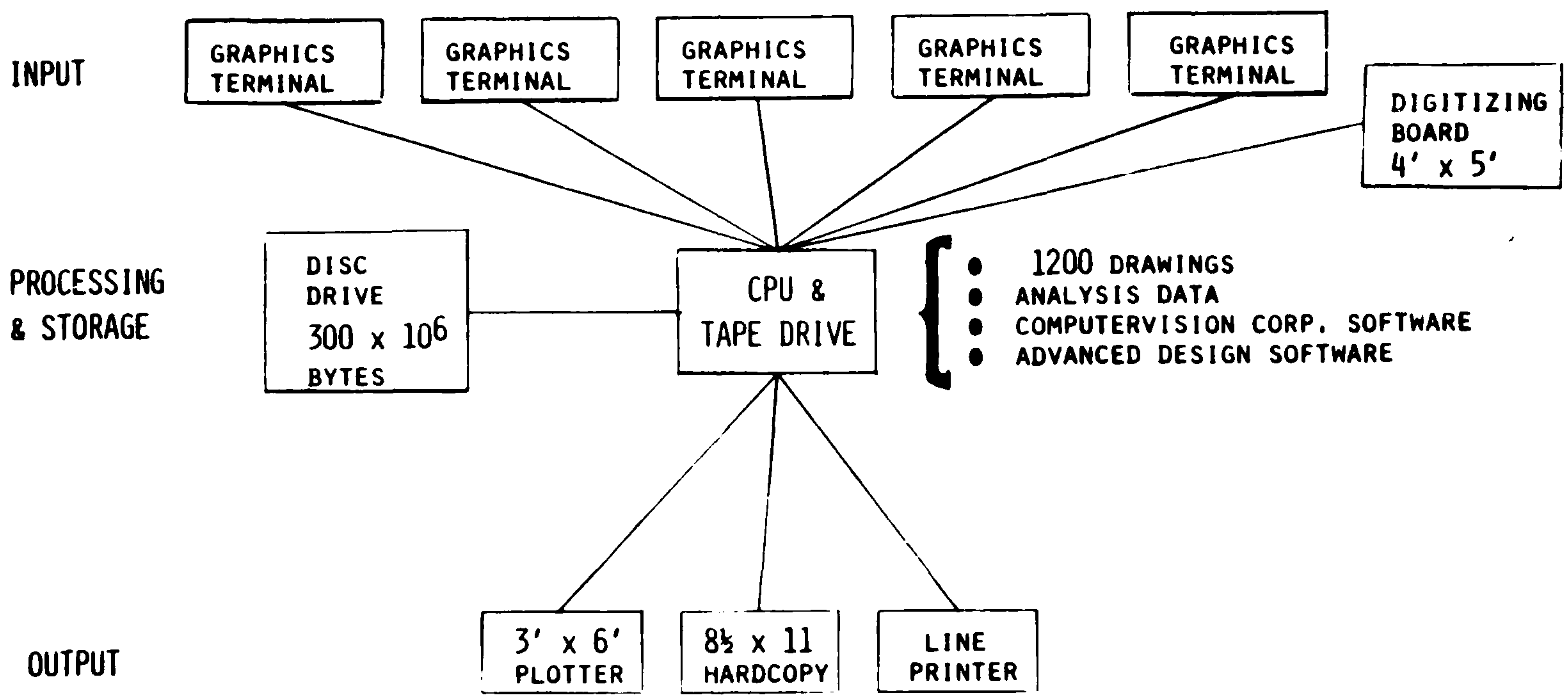
- INCREASE PRODUCTIVITY
    - DECREASE TIME SPENT
    - INCREASE TECHNICAL QUALITY
    - IMPROVE DRAWING QUALITY AND CONSISTENCY
    - INCREASE PROPOSAL QUALITY
    - DECREASE TEDIOUS REPETITIVE WORK
    - DECREASE COST OF FINISHED ART WORK
    - IMPROVE DEPARTMENTAL DATA EXCHANGE

BY

DEVELOPING A COMPUTER GRAPHICS SYSTEM
FOR USE IN ADVANCED DESIGN

SYSTEMS ARCHITECTURE

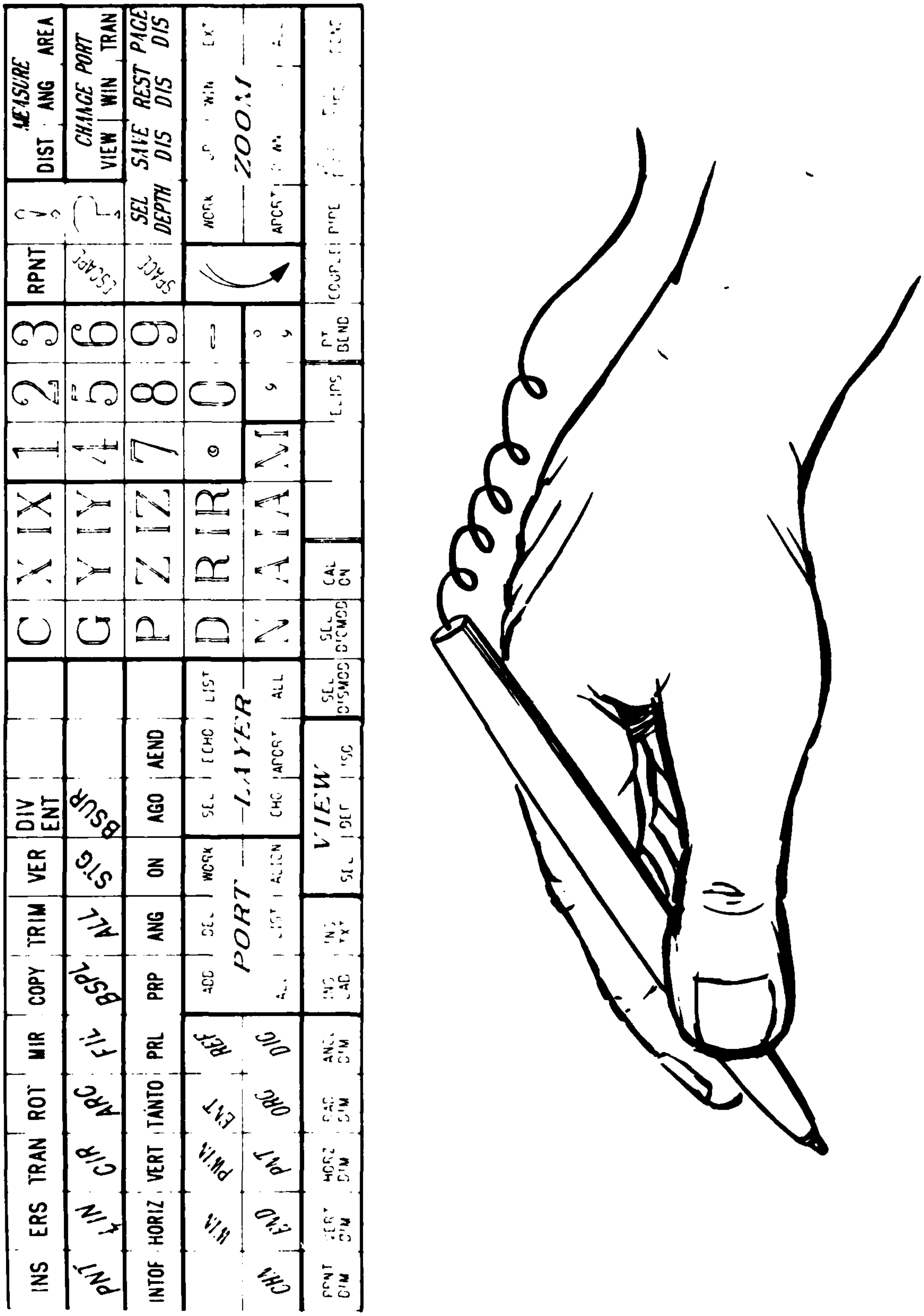
COMPUTERVISION MINICOMPUTER



INPUT FORMAT

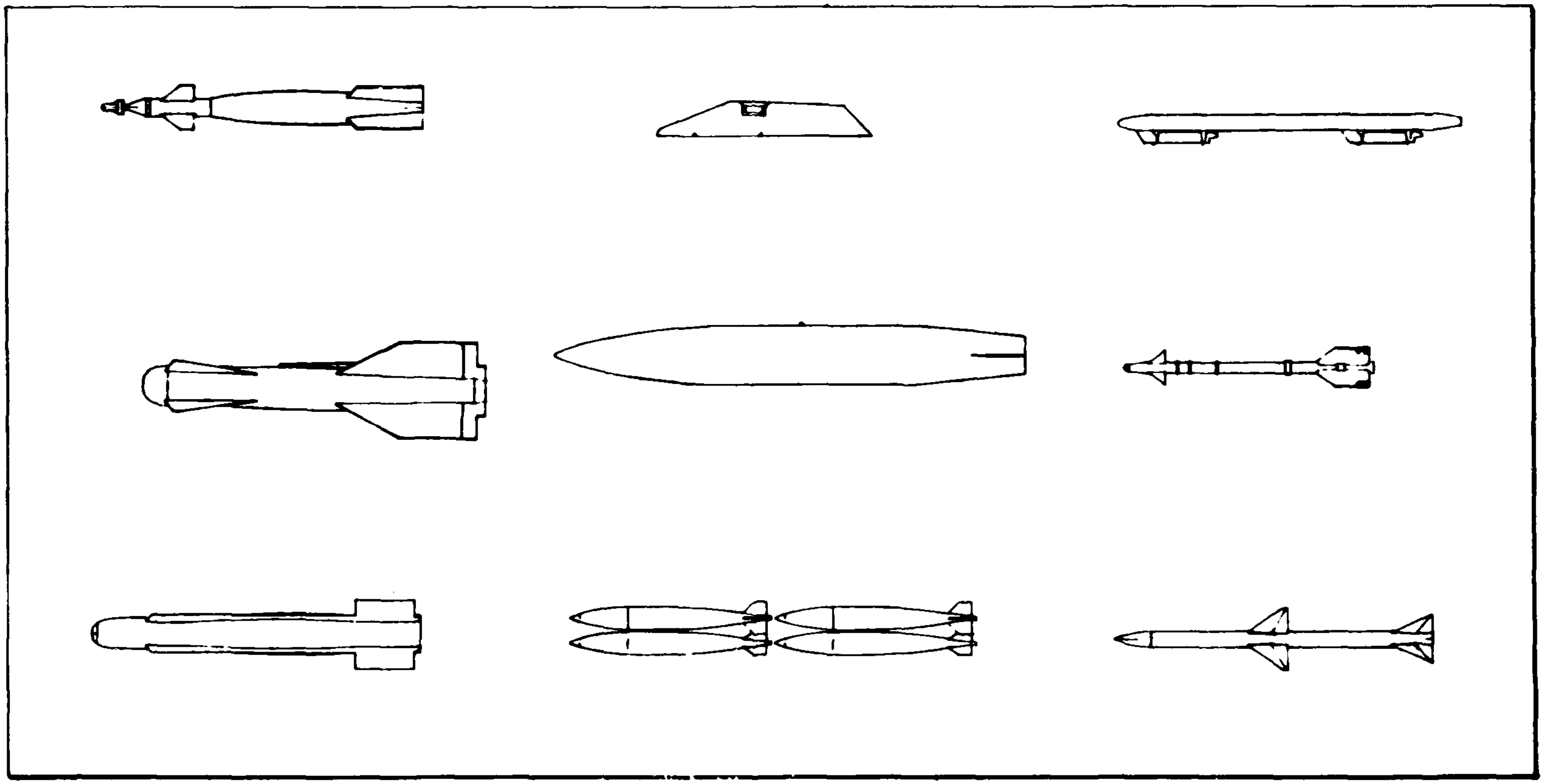
GEOMETRIC DATA	DRAWINGS → DIGITIZING PEN	
	DATA → KEYBOARD	


DISPLAY

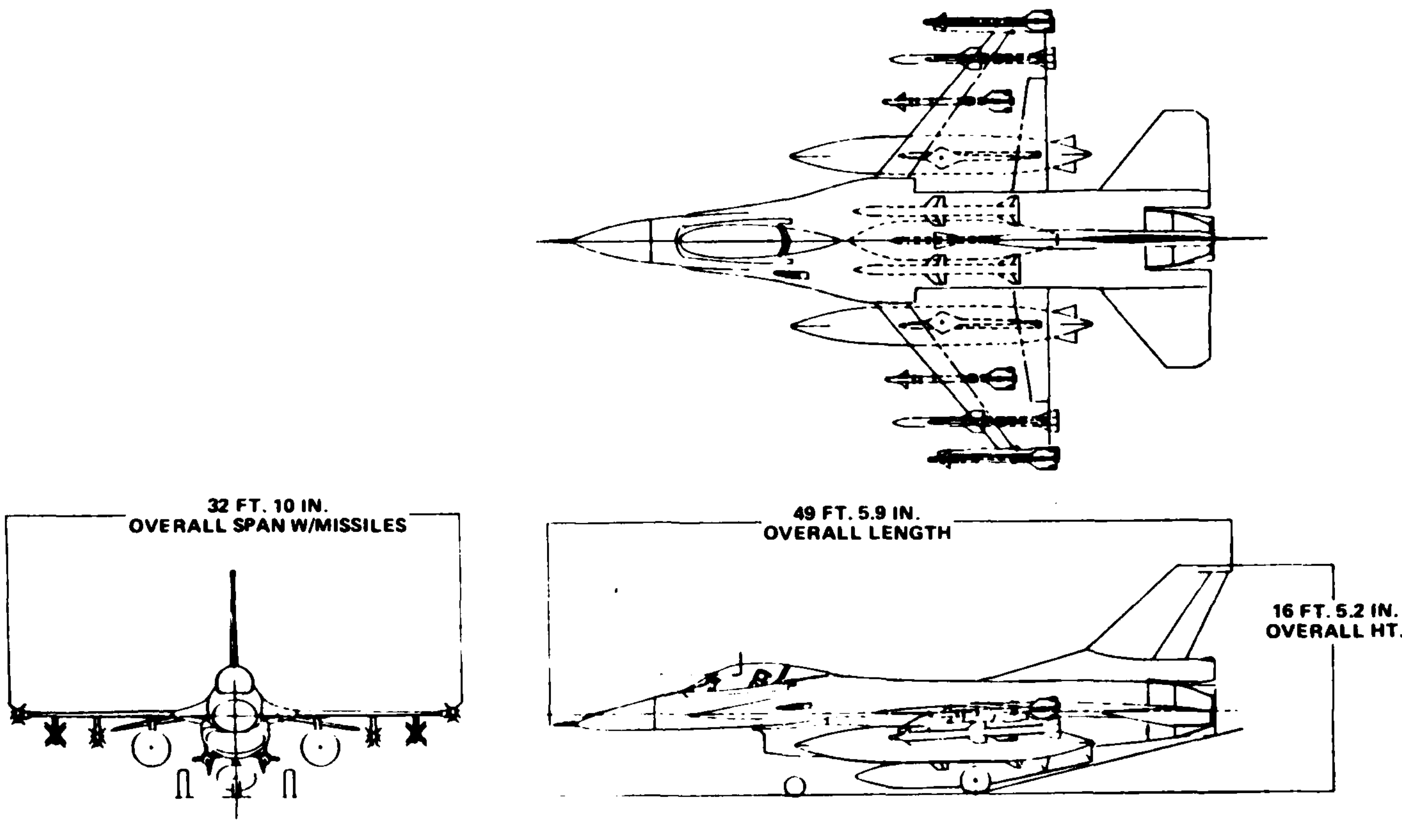


INS
ERS
TRAN
ROT
MIR
COPY
TRIM
VER
DIV ENT
C
X
I
X
1
2
3
RPNT
MEASURE
DIST
ANG
AREA
LIN
CIR
ARC
FIL
BSPL
ALL
STG
BSUR
G
Y
I
Y
4
5
6
CHANGE PORT
VIEW
WIN
TRAN
INTOF
HORIZ
VERT
TANTO
PRL
PRP
ANG
ON
AGO
AEND
P
Z
I
Z
7
8
9
SPACE
SEL DEPTH
SAVE DIS
REST DIS
PAGE DIS
PORT
LAYER
D
R
I
R
C
ZOOM
N
A
I
A
M
VIEW

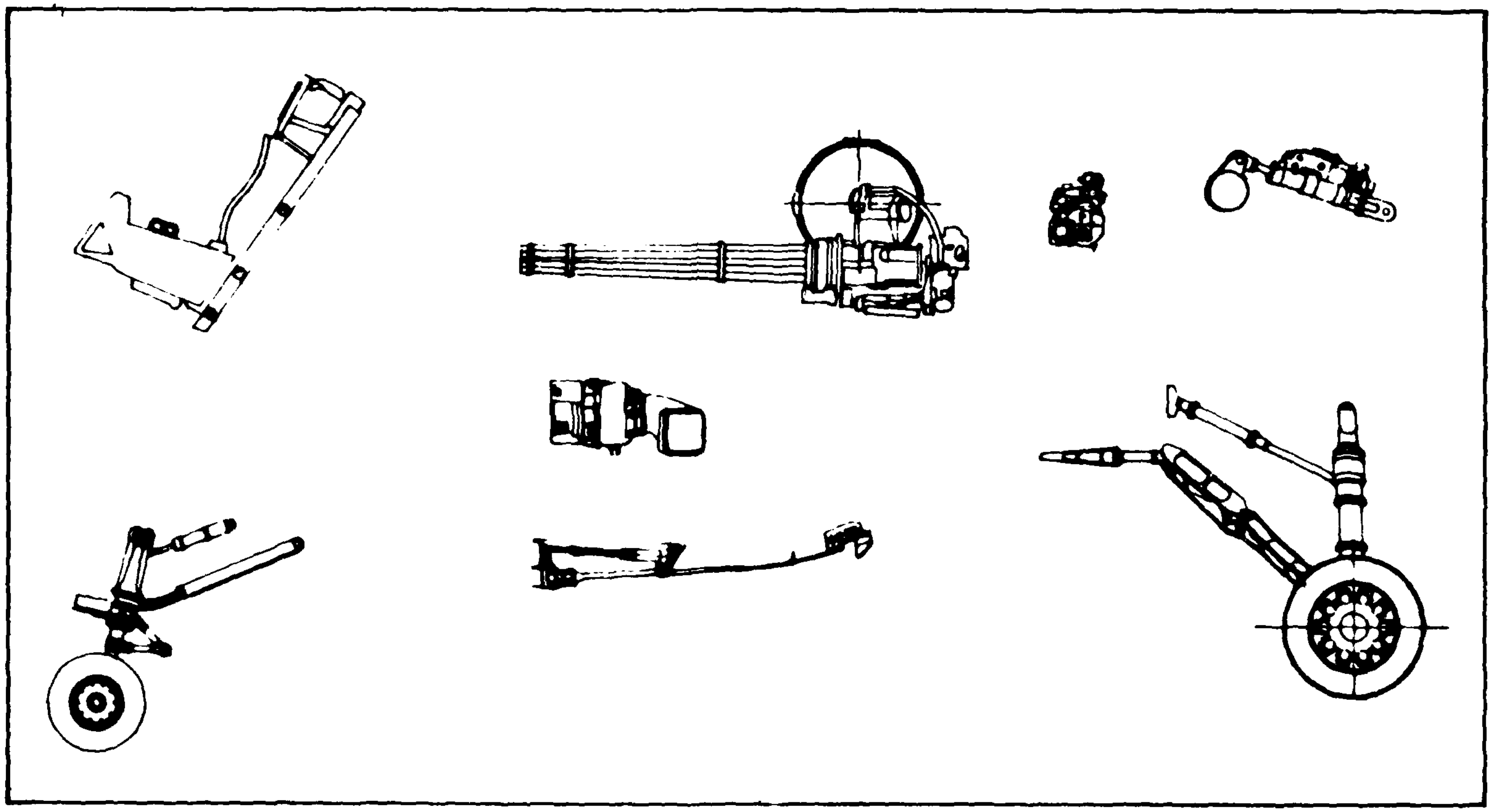
STORES LIBRARY ESTABLISHED



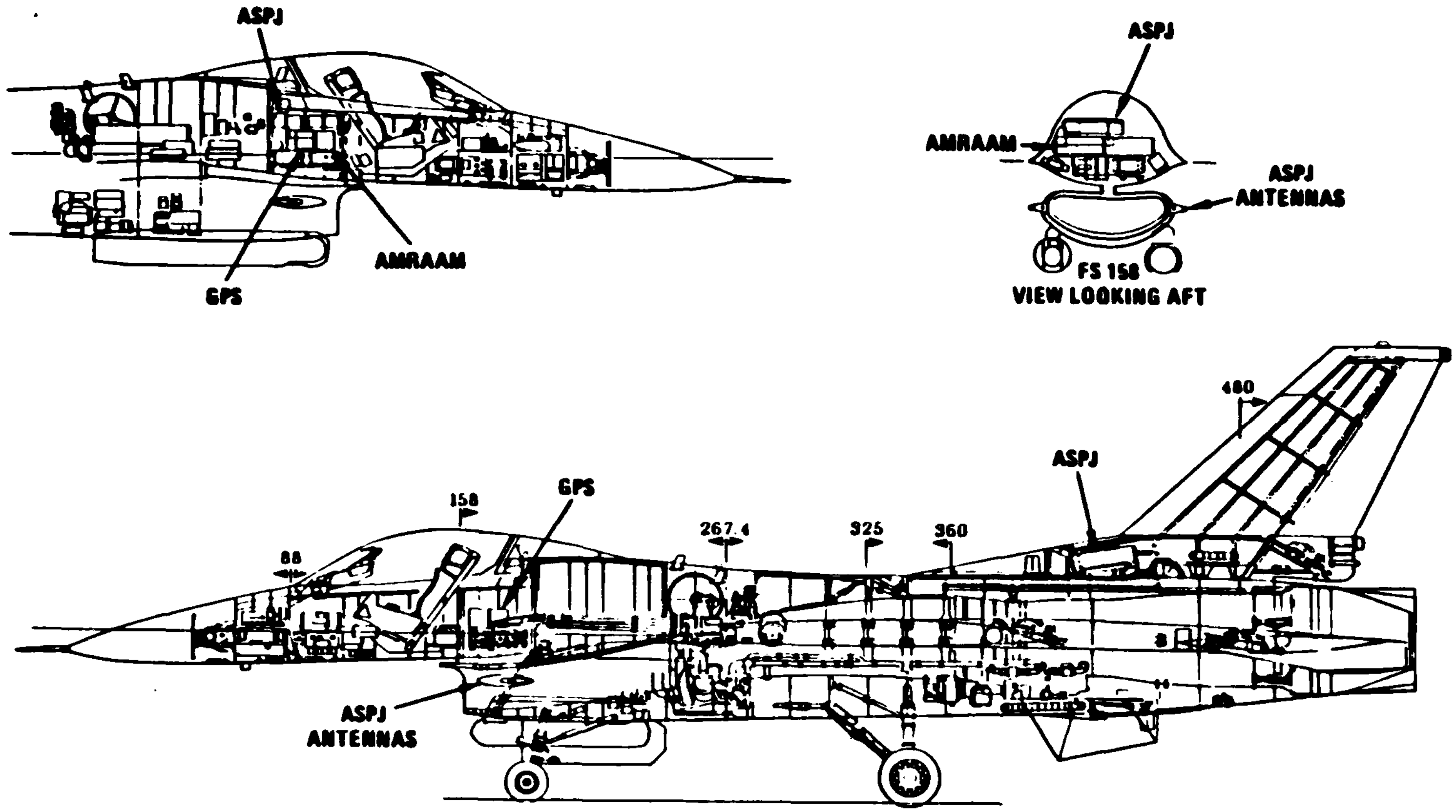
F-16 THREE VIEWS



PARTS LIBRARY ESTABLISHED

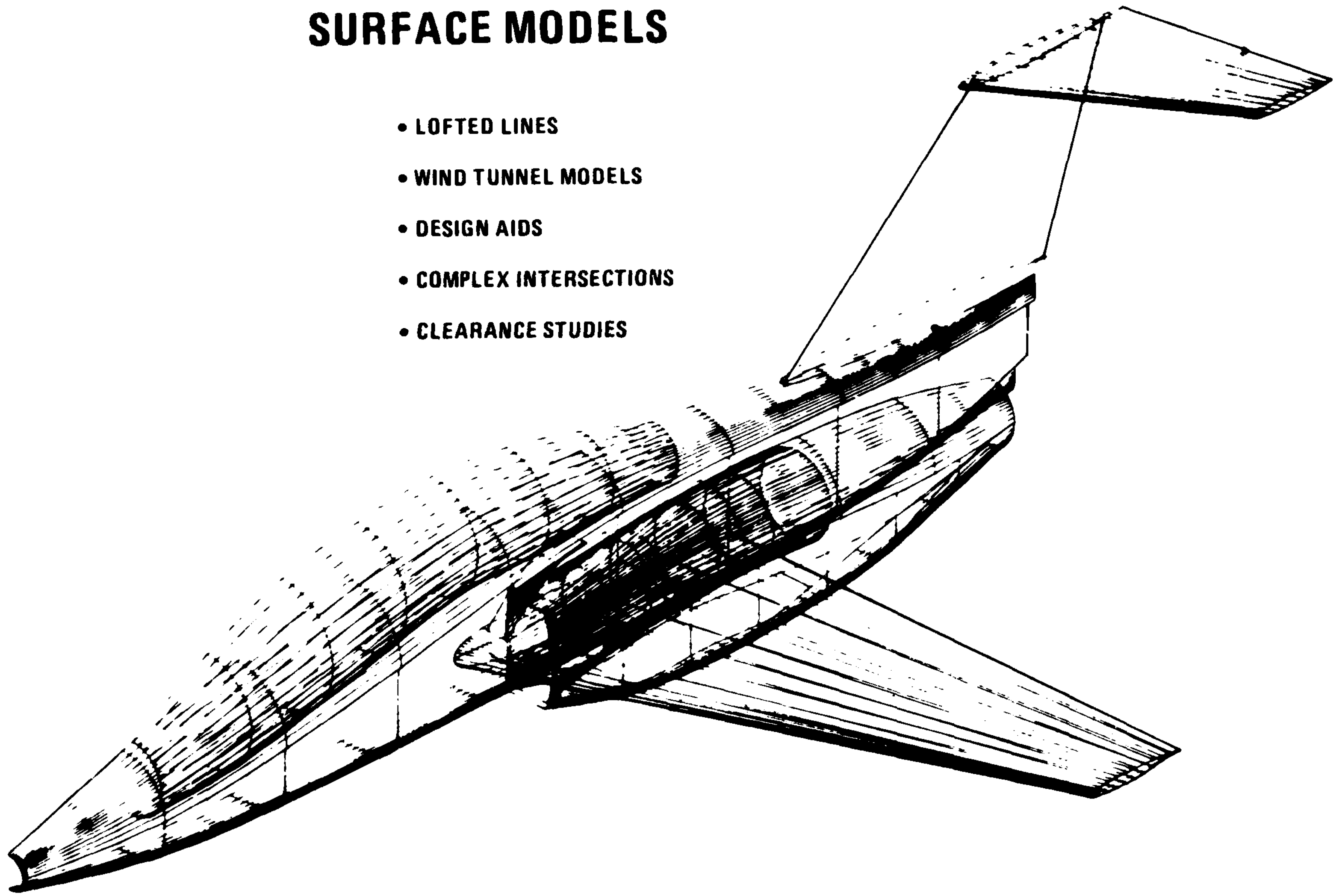


EXAMPLES OF INTERNAL ARRANGEMENT

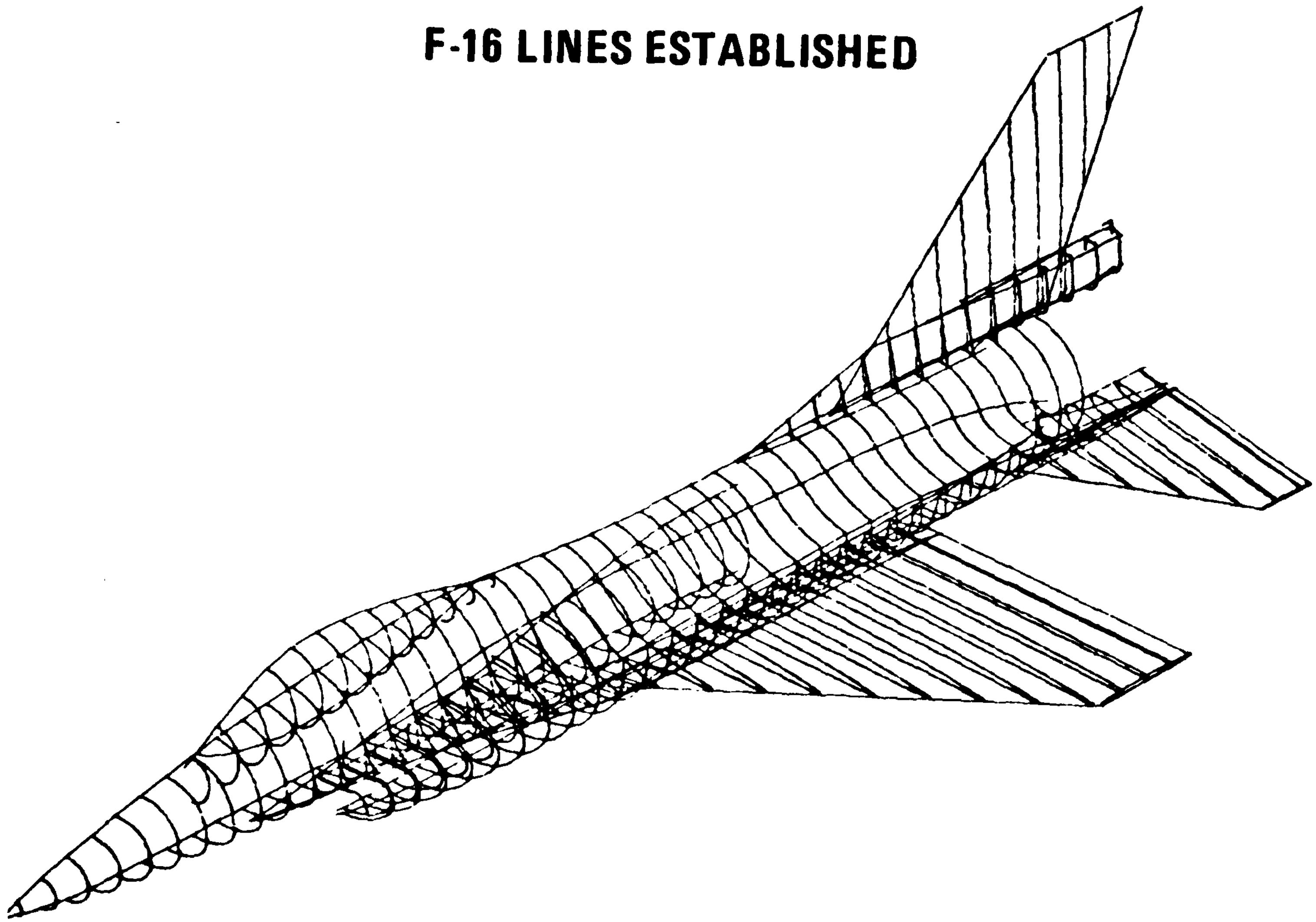


SURFACE MODELS

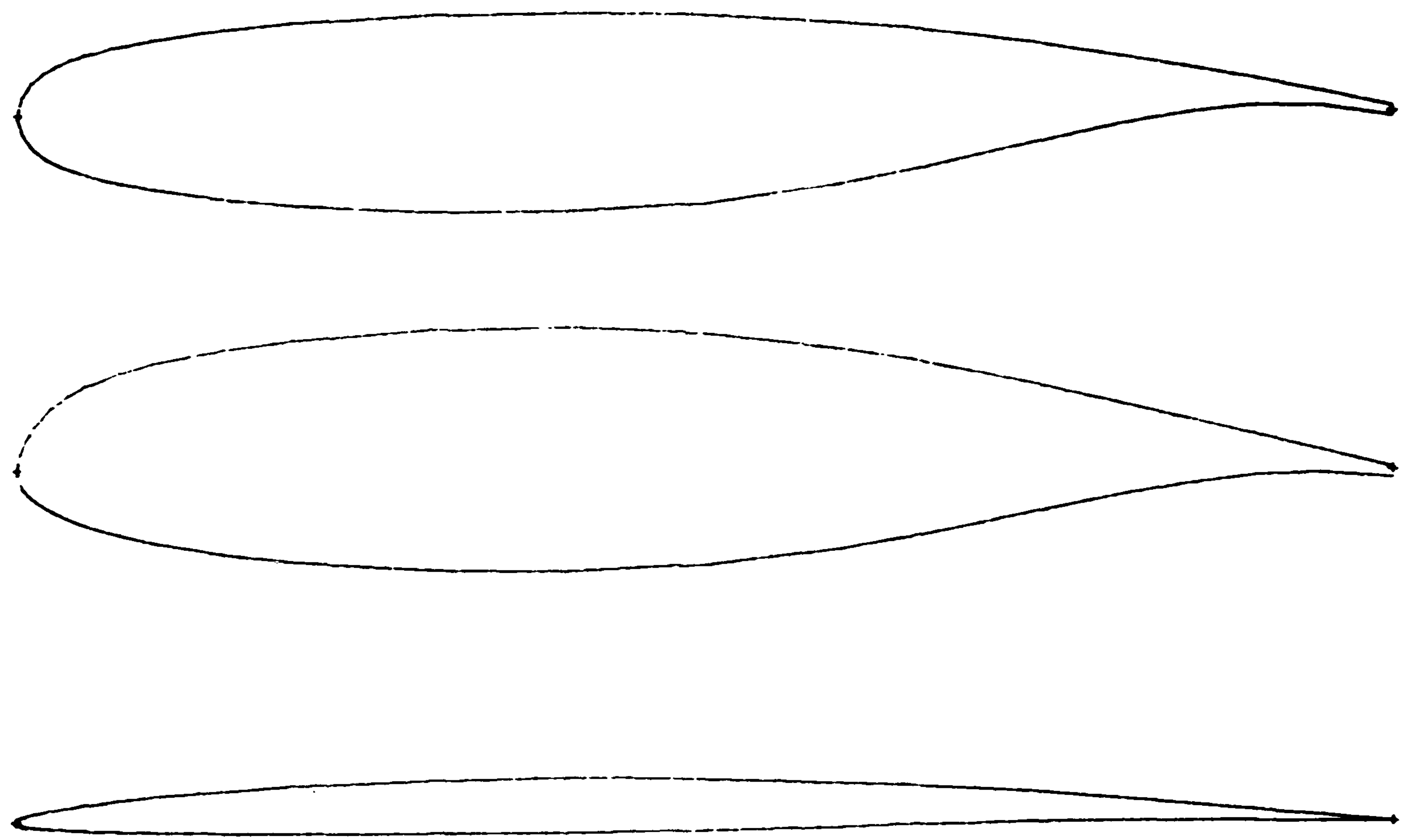
- LOFTED LINES
- WIND TUNNEL MODELS
- DESIGN AIDS
- COMPLEX INTERSECTIONS
- CLEARANCE STUDIES



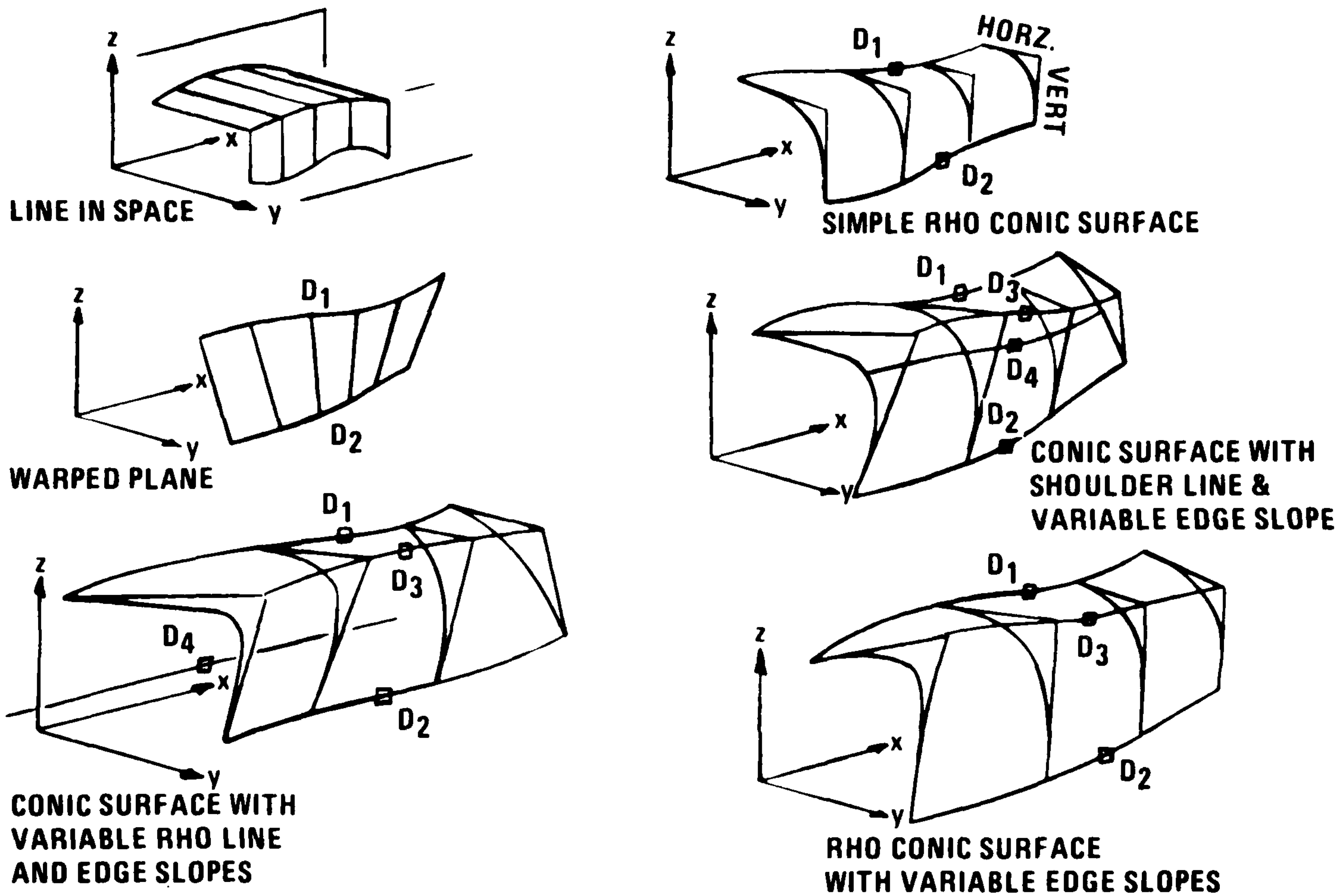
F-16 LINES ESTABLISHED



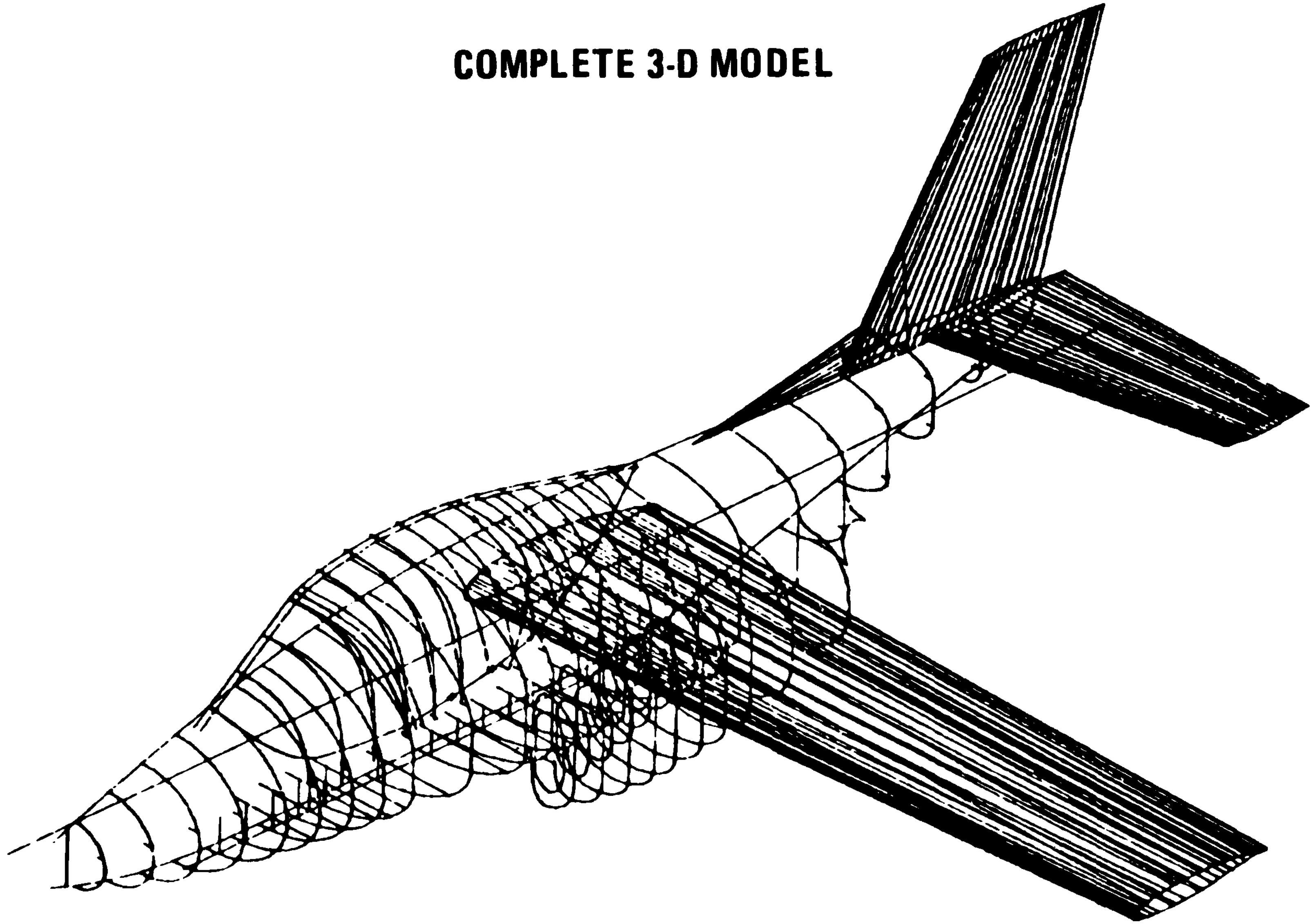
AIRFOIL LIBRARY ESTABLISHED



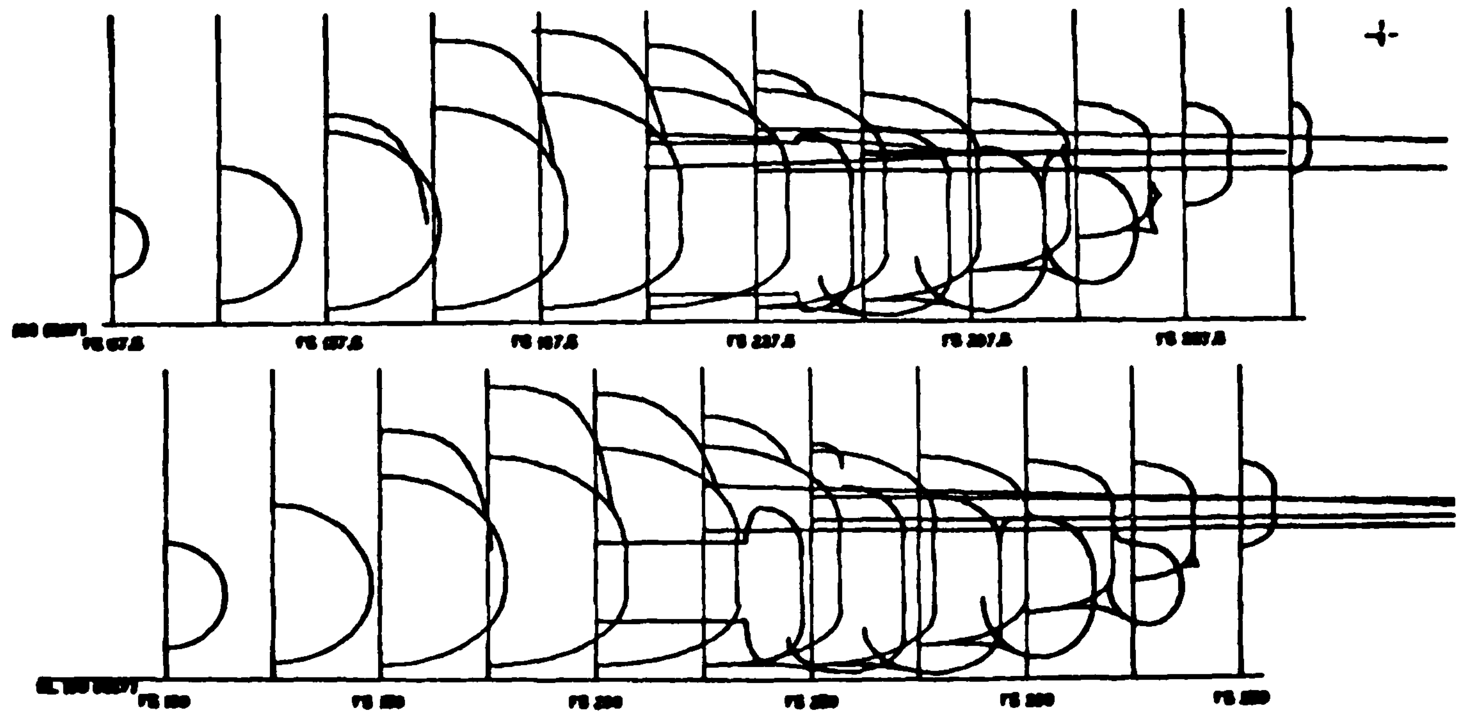
FORT WORTH USES PLOYCONIC SURFACES



COMPLETE 3-D MODEL

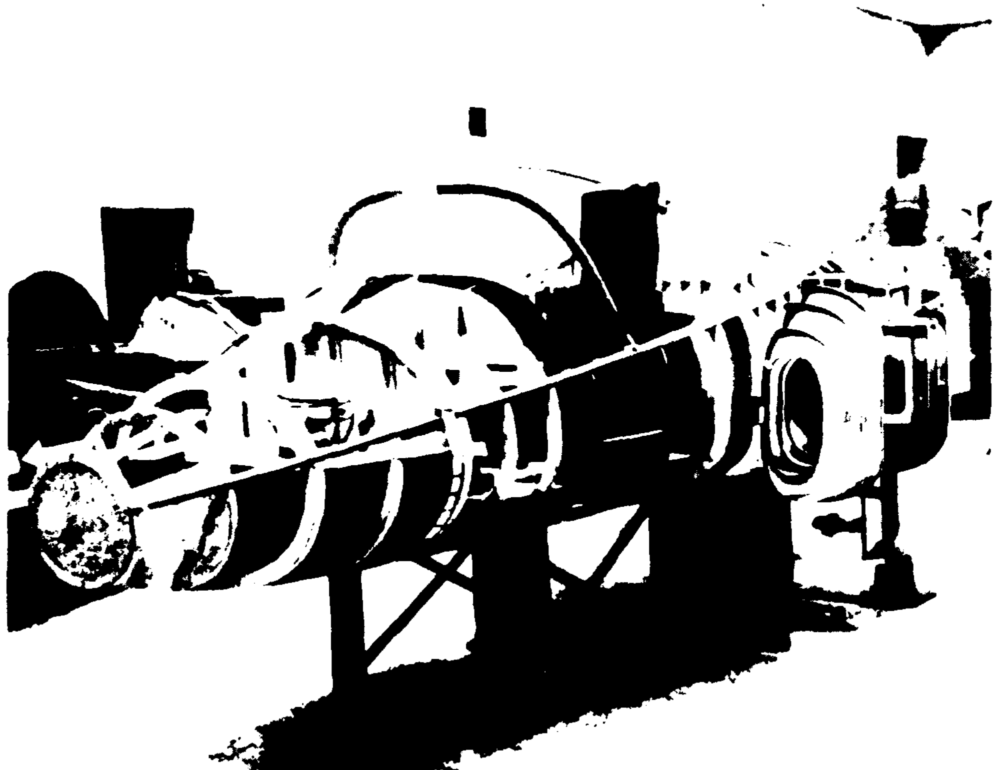


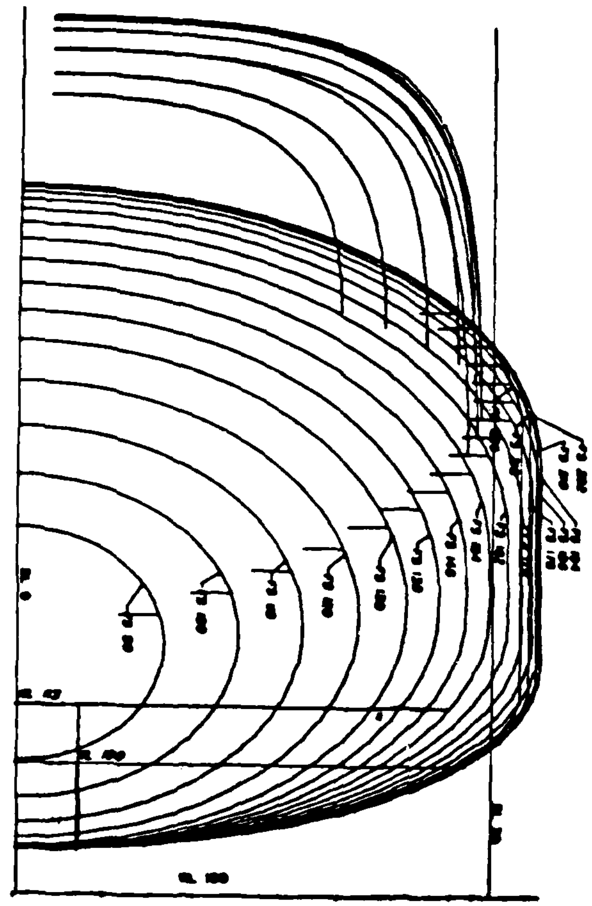
WIND TUNNEL MODEL CROSS SECTIONS



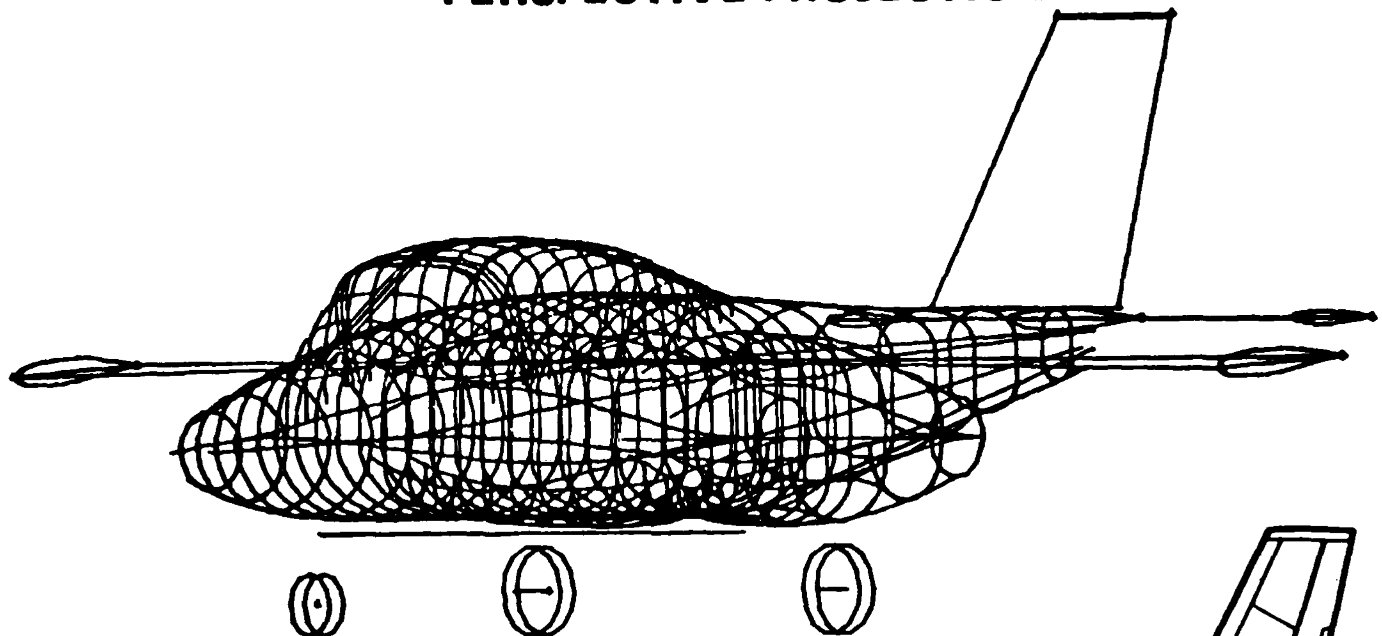

LST789-0
RUN 25

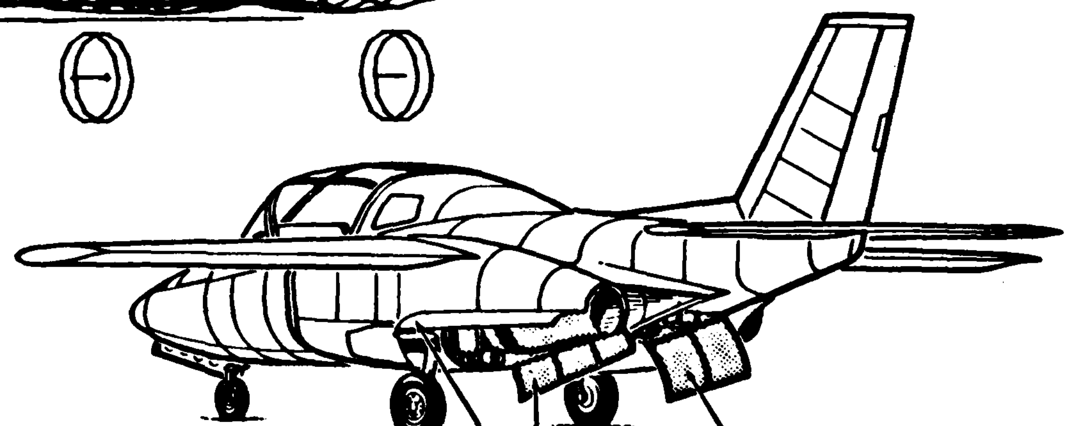
FULL SCALE MOCKUP SECTIONS



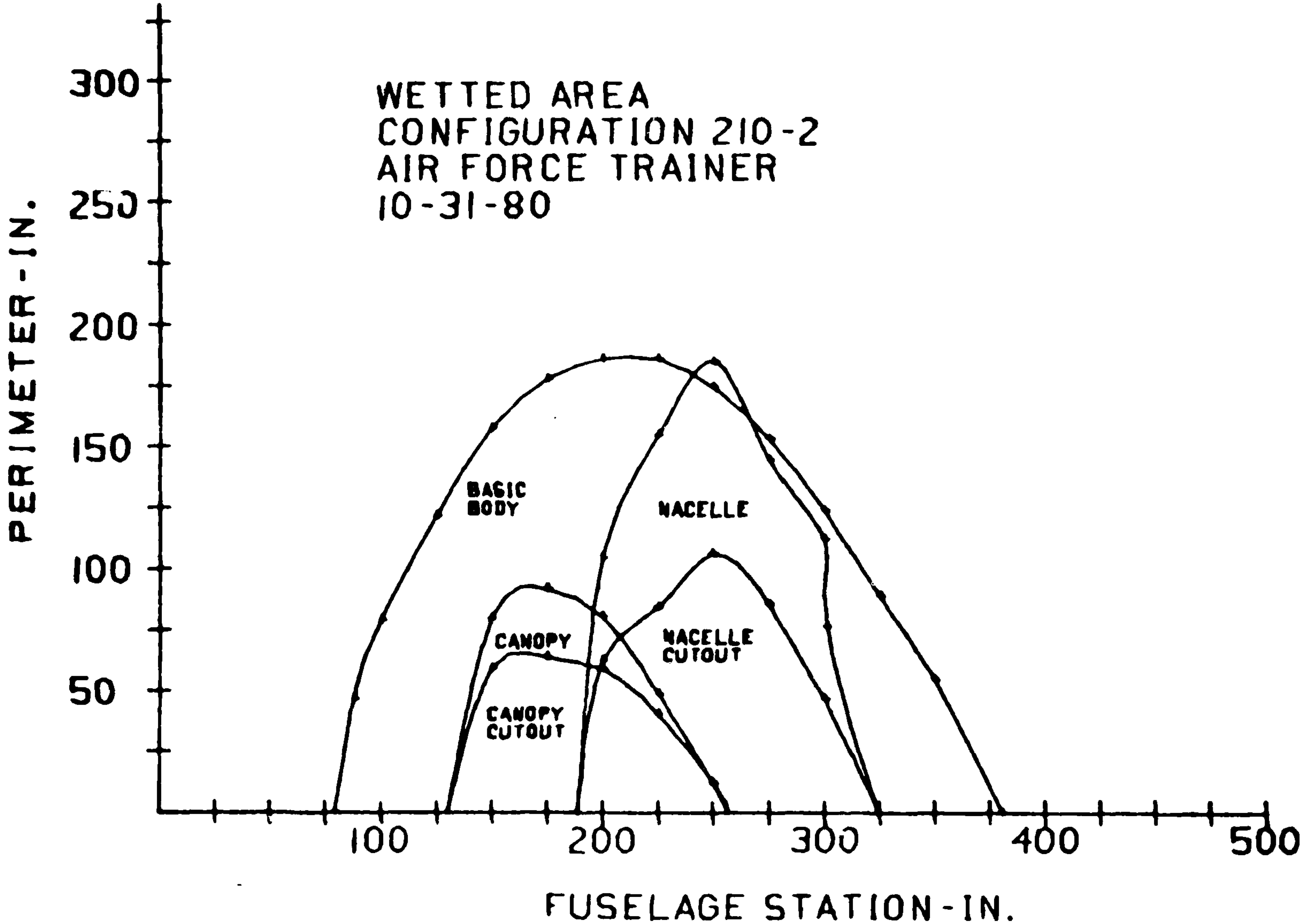


PERSPECTIVE PROJECTION



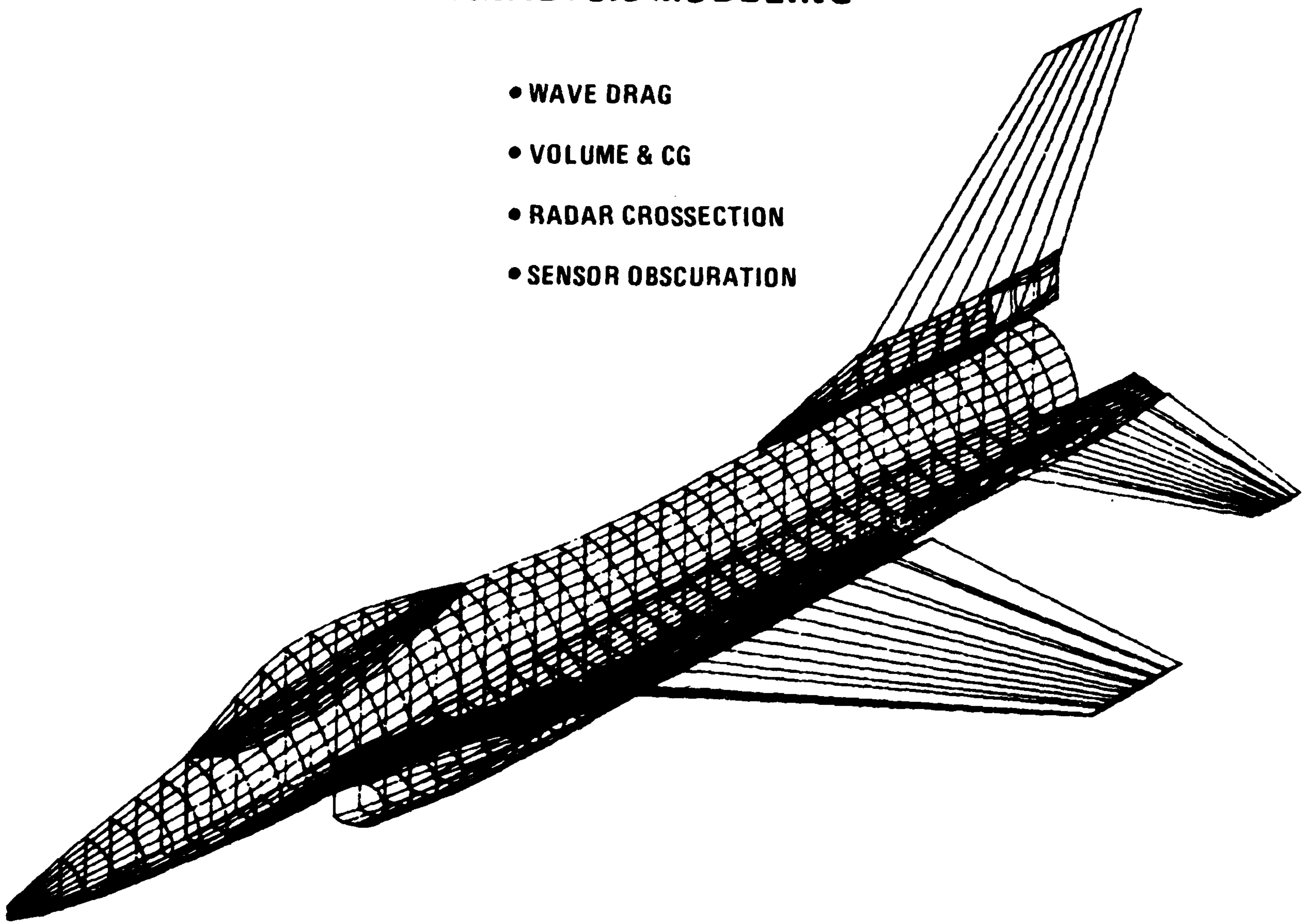


WETTED AREA PLOTS

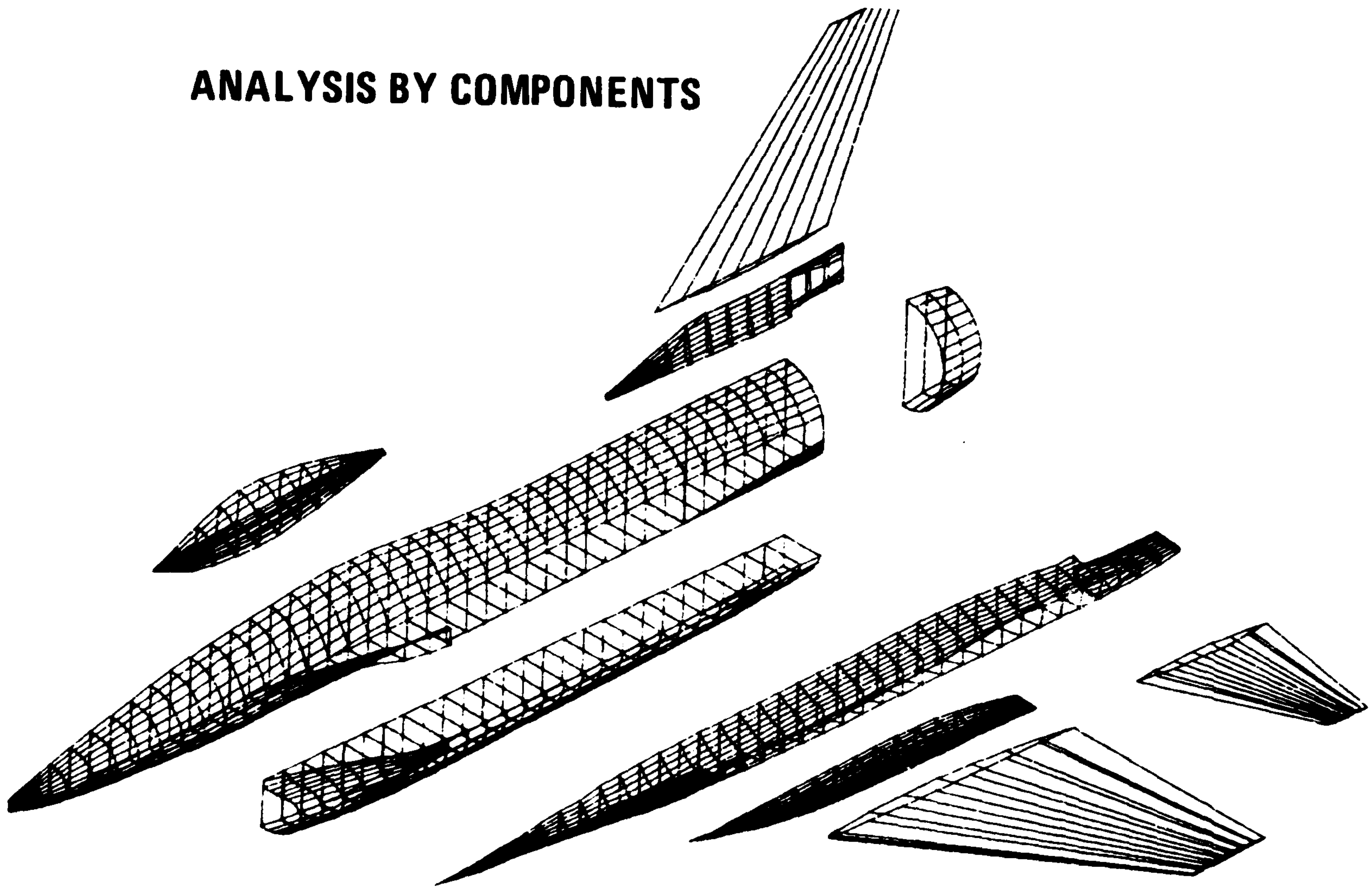


ANALYSIS MODELING

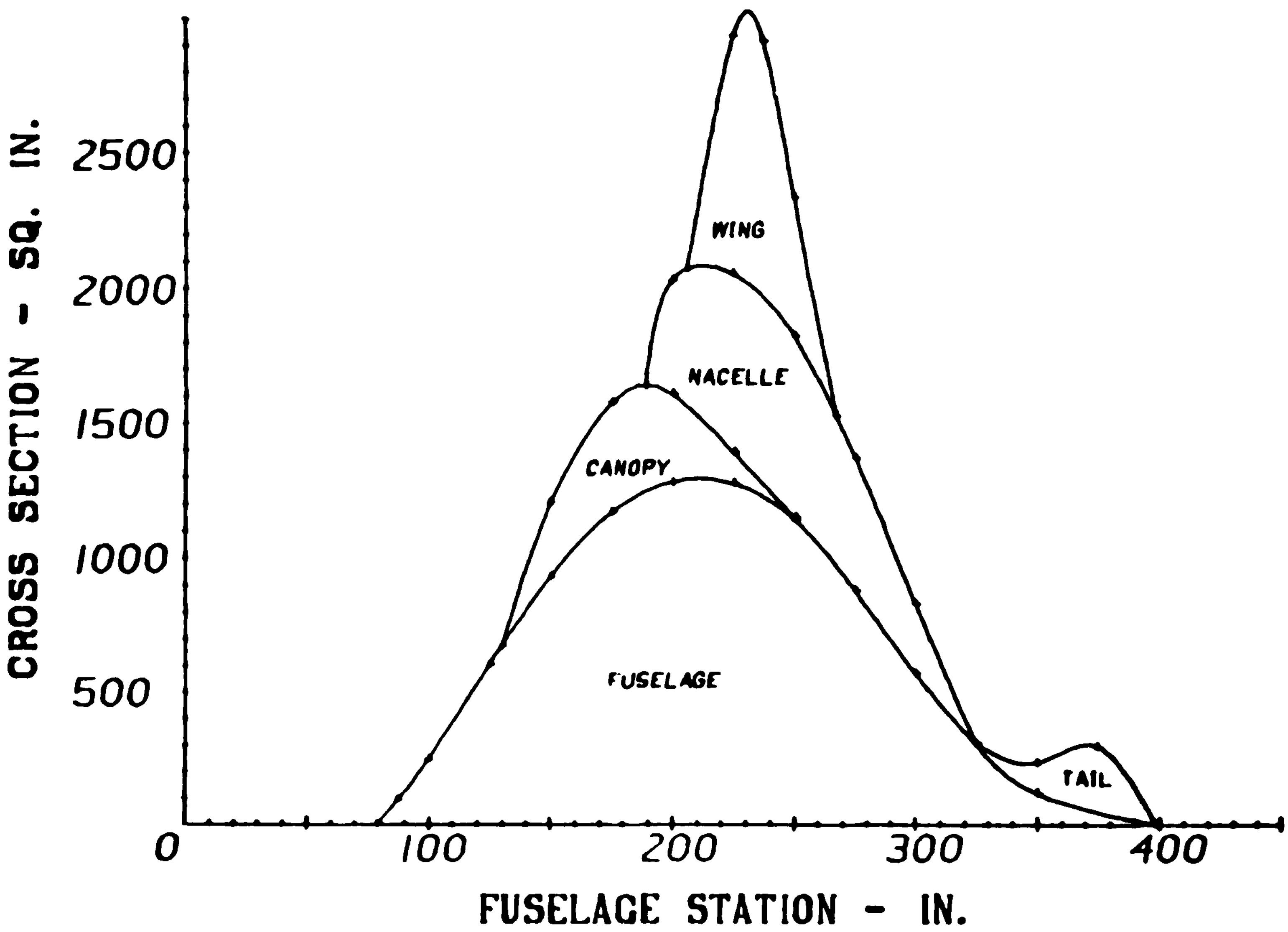
- WAVE DRAG
- VOLUME & CG
- RADAR CROSSECTION
- SENSOR OBSCURATION



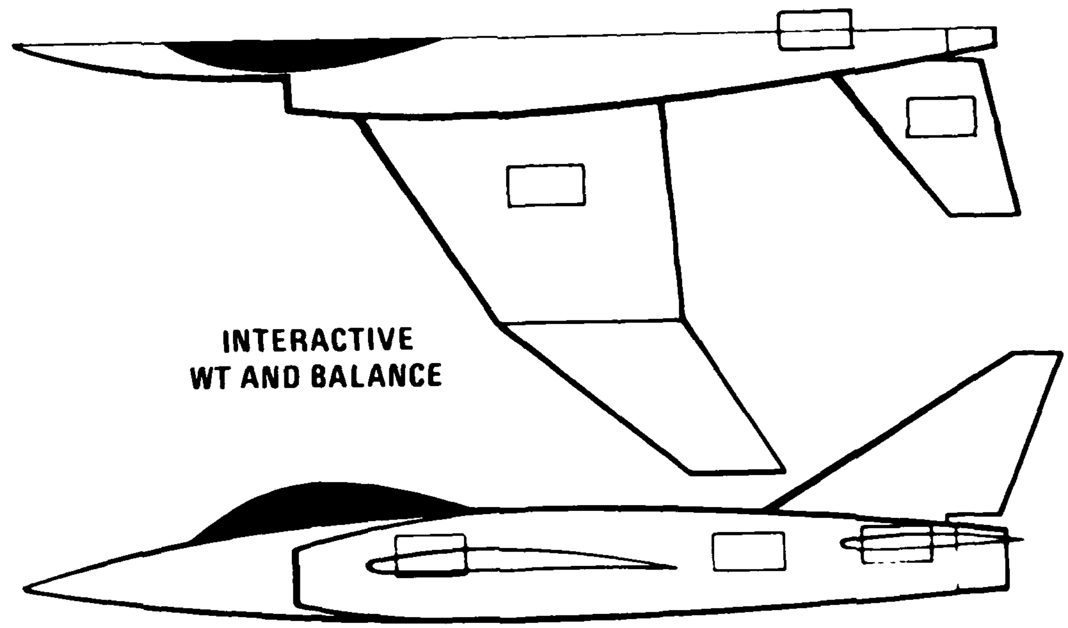
ANALYSIS BY COMPONENTS



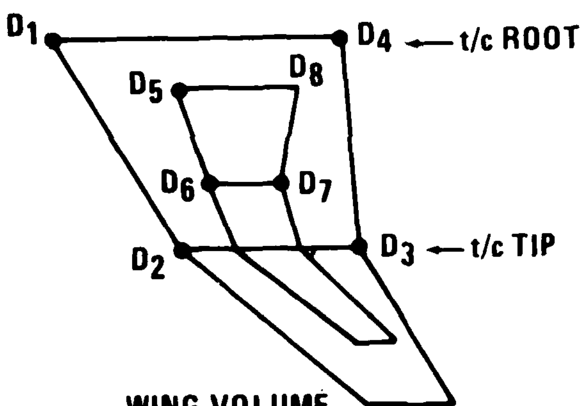
CROSS-SECTION AREA PLOTS



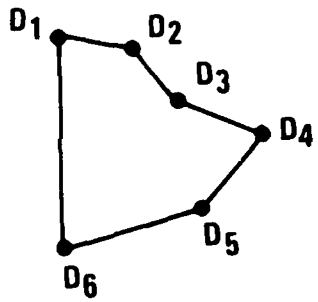
INTERACTIVE ANALYSIS FOR MANY PURPOSES



INTERACTIVE
WT AND BALANCE

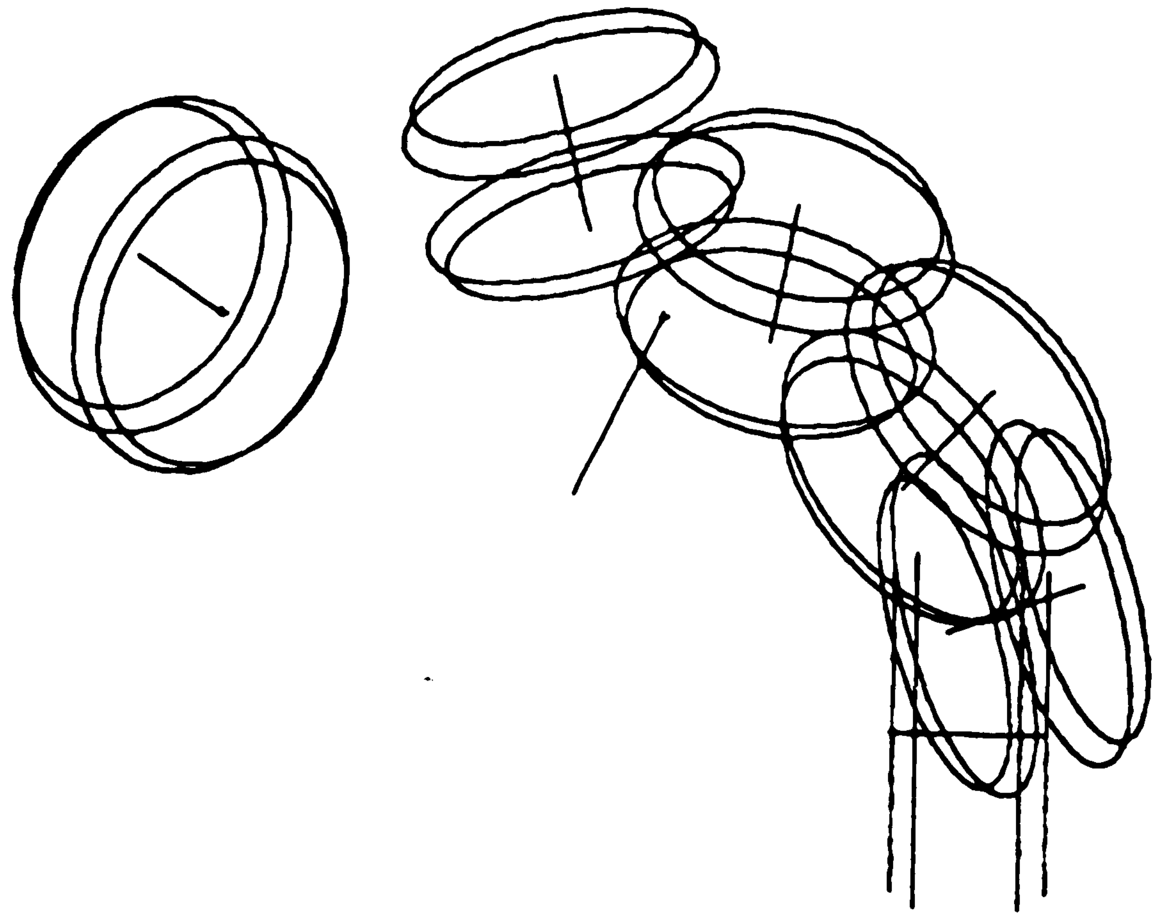


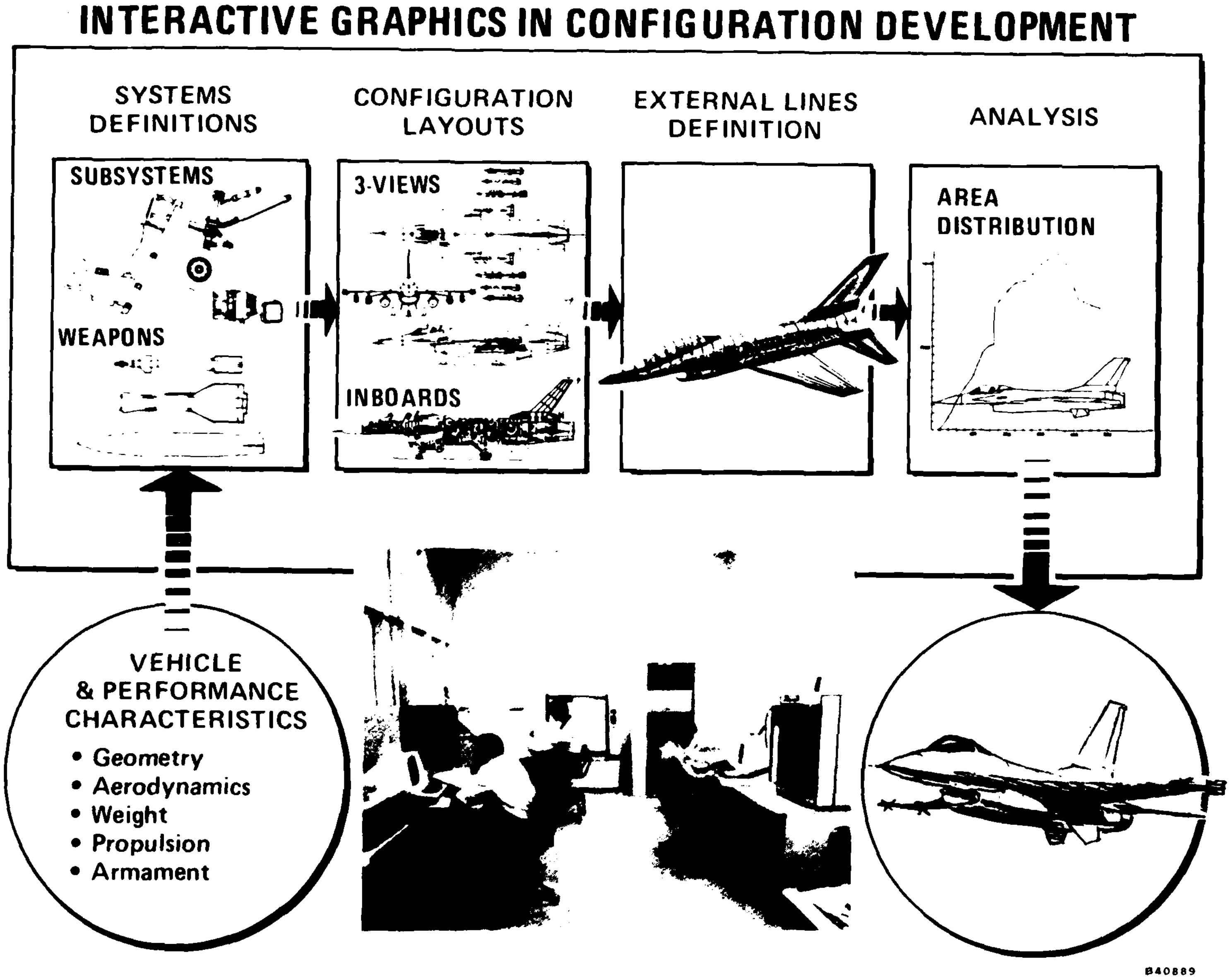
WING VOLUME



CROSSECTIONAL
AREA

EXAMPLE OF LANDING GEAR MOTION




INTERACTIVE GRAPHICS IN CONFIGURATION DEVELOPMENT
SYSTEMS DEFINITIONS
SUBSYSTEMS
WEAPONS
CONFIGURATION LAYOUTS
3-VIEWS
INBOARDS
EXTERNAL LINES DEFINITION
ANALYSIS
AREA DISTRIBUTION
VEHICLE & PERFORMANCE CHARACTERISTICS
• Geometry
• Aerodynamics
• Weight
• Propulsion
• Armament
B40889

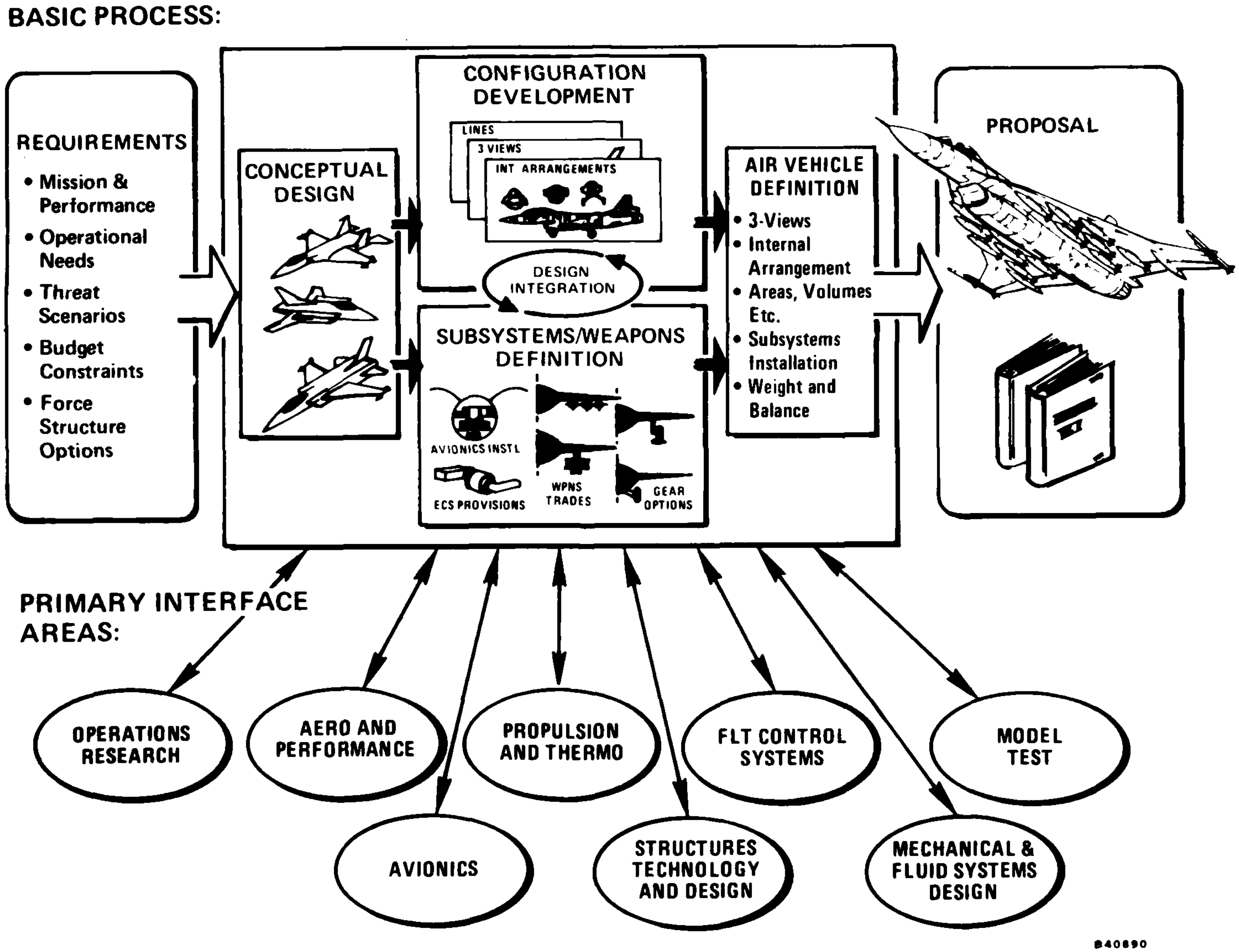
MILITARY AIRCRAFT CONCEPTUAL
DESIGN TRENDS FOR THE 80's

S. Keith Jackson
General Dynamics
Ft. Worth, Texas

MILITARY AIRCRAFT CONCEPTUAL DESIGN TRENDS FOR THE 80'S

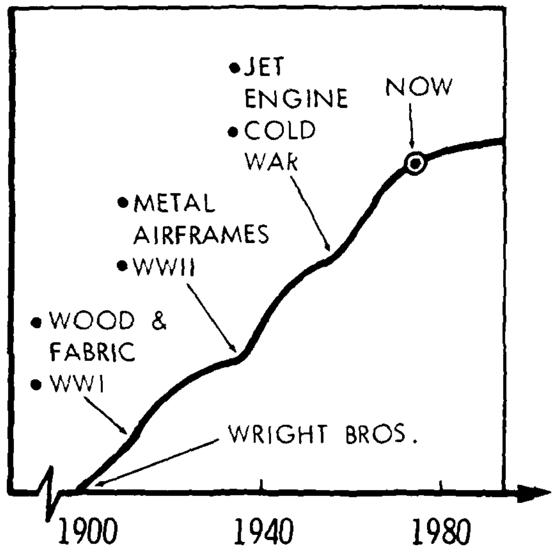
- OVERVIEW OF RECENT TRENDS
- THE EVOLVING CONCEPTUAL DESIGN PROCESS
- ANALYTICAL TOOLS
  - SCREENING ANALYSES
  - THE CONCEPTUAL DESIGN SYNTHESIS PROCEDURE
  - EFFECTIVENESS MODELS

THE ADVANCED DESIGN PROCESS

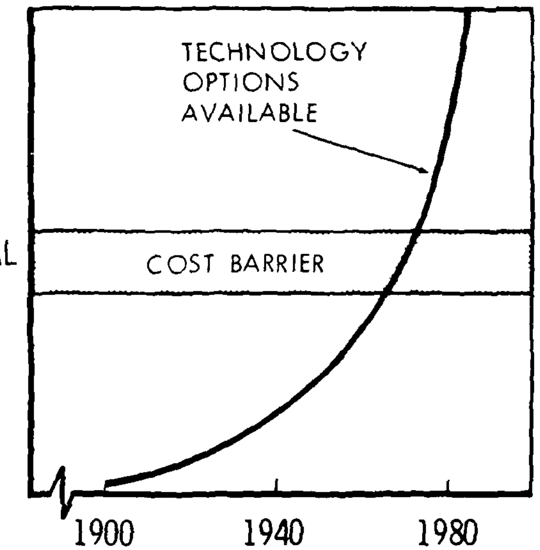


THE WORLD IS CHANGING

DEGREE
OF
DEVELOPMENT
OF
MAJOR
AIRFRAME
TECHNOLOGIES
- Aero
- Propulsion
- Structure



NUMBER
OF
IMPORTANT
TECHNOLOGICAL
OPTIONS



INDIVIDUAL AIRFRAME TECHNOLOGIES ARE APPROACHING MATURITY

BUT

OVERALL OPTIONS ARE INCREASING RAPIDLY . . . ARE COST CONSTRAINED

RESULT: A SHIFTING EMPHASIS IN CONCEPTUAL DESIGN

FW76 274 · VG5851
6 APRIL '76

THE SHIFTING EMPHASIS

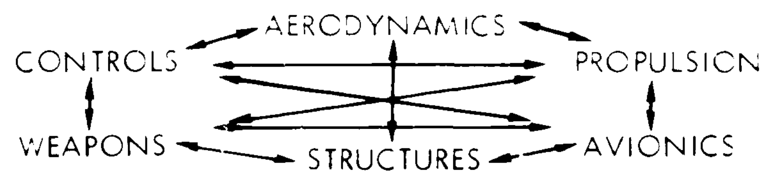
IN THE PAST

- AIRCRAFT TENDED TO BE BUILT AROUND "INDIVIDUAL" TECHNOLOGIES
  - High HP Wt Int. Combustion Eng.
  - Metal-Monocoque Structures
  - Jet Engine
  - Supersonic Aerodynamics

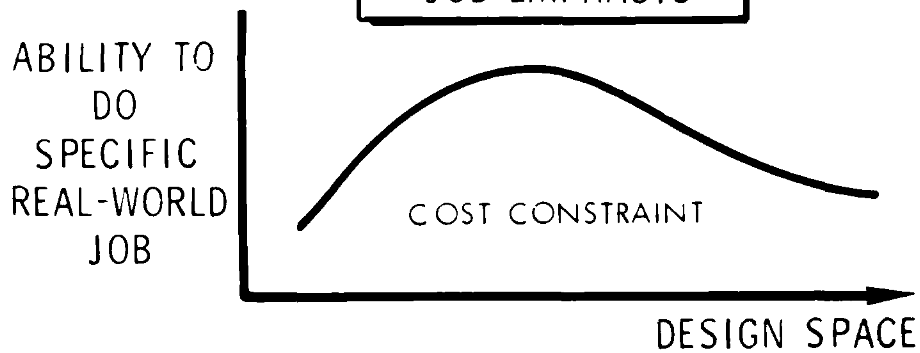
PERFORMANCE EMPHASIS

IN THE FUTURE

- GAINS INCREASINGLY FROM "MULTIDISCIPLINARY" CROSS-COUPLING OF TECHNOLOGIES



JOB EMPHASIS

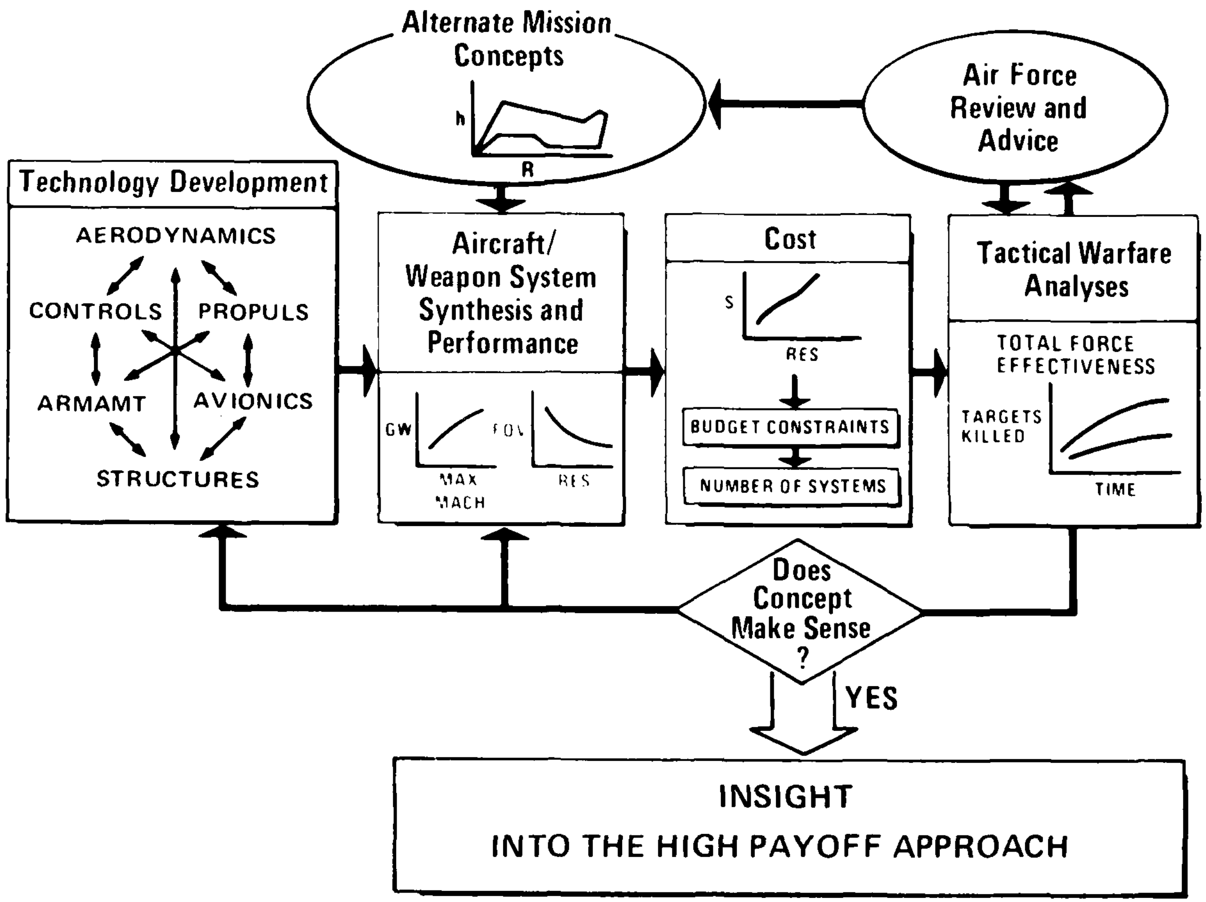


6B5852B

OUR APPROACH

CONSIDER A WIDE RANGE OF

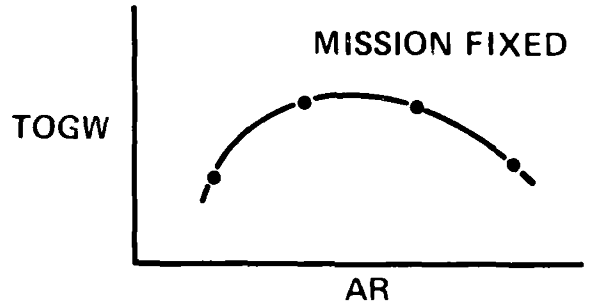
- Mission Variations
- Technologies
- Design Concepts



B8869B

THE PROBLEM WITH DATA

- A MINIMUM OF 3 TO 5 "AIRPLANES" ARE NEEDED TO DEFINE A SINGLE-VARIABLE OPTIMUM . . .



- AND THERE ARE A LOT OF VARIABLES

MISSION	MAJOR DESIGN	ENGINE	PAYLOAD	SCENARIO
• Range	• Thrust	• BPR	• Radar	• Threat Types
• Payload	• S	• OPR	• EO	• Threat Numbers
• Combat Allowance	• AR	• T.I.T.	• ECM	• Threat Tech
• $M_{Max.}$	• t/c	• θ Break	• Crew Size	• Target Types
• M_{Cruise}	• λ	• Tech Level	• Gun	• Target Numbers
• G Capability	• Λ LE	• Thrust Rev?	• "Armor"	• Weather
• T.O. Dist	• l_f	• Component Eff.		• Support Forces
• Land Dist	• Tail Location/Type			• Tactics
• Accel Time	• No. Engines			
	• Stealth Shaping			
	• Inlet			
	• Nozzle			
	• Equipment Tech.			

6R2029A

CONCEPTUAL

DESIGN

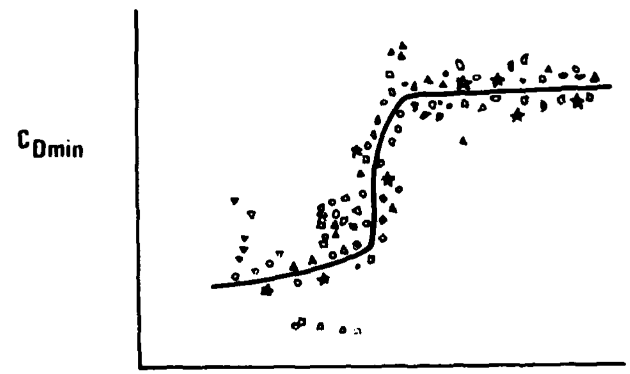
SYNTHESIS

PROCEDURE

CDSP

A WORD ON ACCURACY

F-16 MINIMUM DRAG
FLIGHT TEST DATA



- "ABSOLUTE" ACCURACY IS <u>OFTEN</u> . . . .
  - AN ILLUSION
  - EXPENSIVE
  - TIME CONSUMING

  ⇩

  - COUNTERPRODUCTIVE
- BUT SMALL <u>DIFFERENCES</u> CAN STILL BE IMPORTANT

- MANY CONCEPTUAL/PRELIMINARY DESIGN PROBLEMS ARE BY NATURE IMPRECISE
- MOST IMPORTANT ERRORS COME FROM
  - NEGLECTING CRUCIAL VARIABLES
  - BAD INPUT DATA
  - LACK OF FEEL FOR THE ANSWER
- ENORMOUS TEMPTATION TO BE RESISTED (HOWEVER IMPERFECTLY)
  - DOING WHAT YOU KNOW HOW TO DO – IN ULTIMATE DETAIL, WHILE . . .
  - NEGLECTING ENTIRELY WHAT YOU DON'T KNOW EXACTLY HOW TO DO
- THINKING POINTS – WHEN DO I NEED:
  - COMPREHENSIVENESS? • SENSITIVITY? • ACCURACY? • PRECISION?
  - RESPONSE TIME?

⇨ CONCEPTUAL/PRELIMINARY DESIGN NEEDS OFTEN VERY DIFFERENT FROM THOSE OF DETAIL DESIGN

B27116

CDSP – PHILOSOPHICAL BACKGROUND

NEEDS

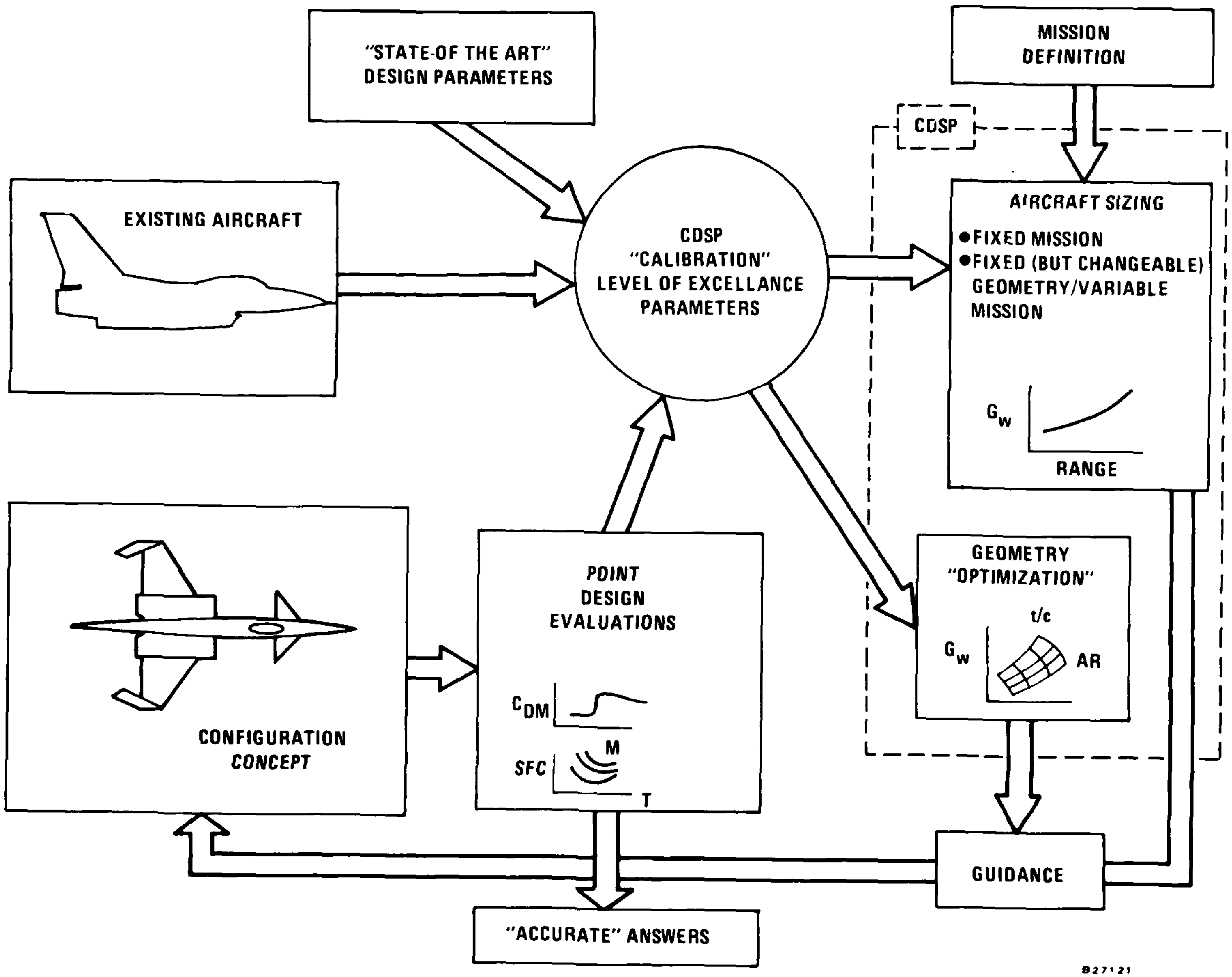
- EFFICIENCY
  - CHEAP ENOUGH FOR BROAD SURVEYS
- GOOD TRENDS FOR BOTH CURRENT AND ADVANCED TECHNOLOGY
- FLEXIBILITY (BUT NOT AT THE EXPENSE OF EFFICIENCY)
- RETAIN DESIGNER AS INTEGRAL PART OF CONFIGURATION DEVELOPMENT PROCESS

APPROACH

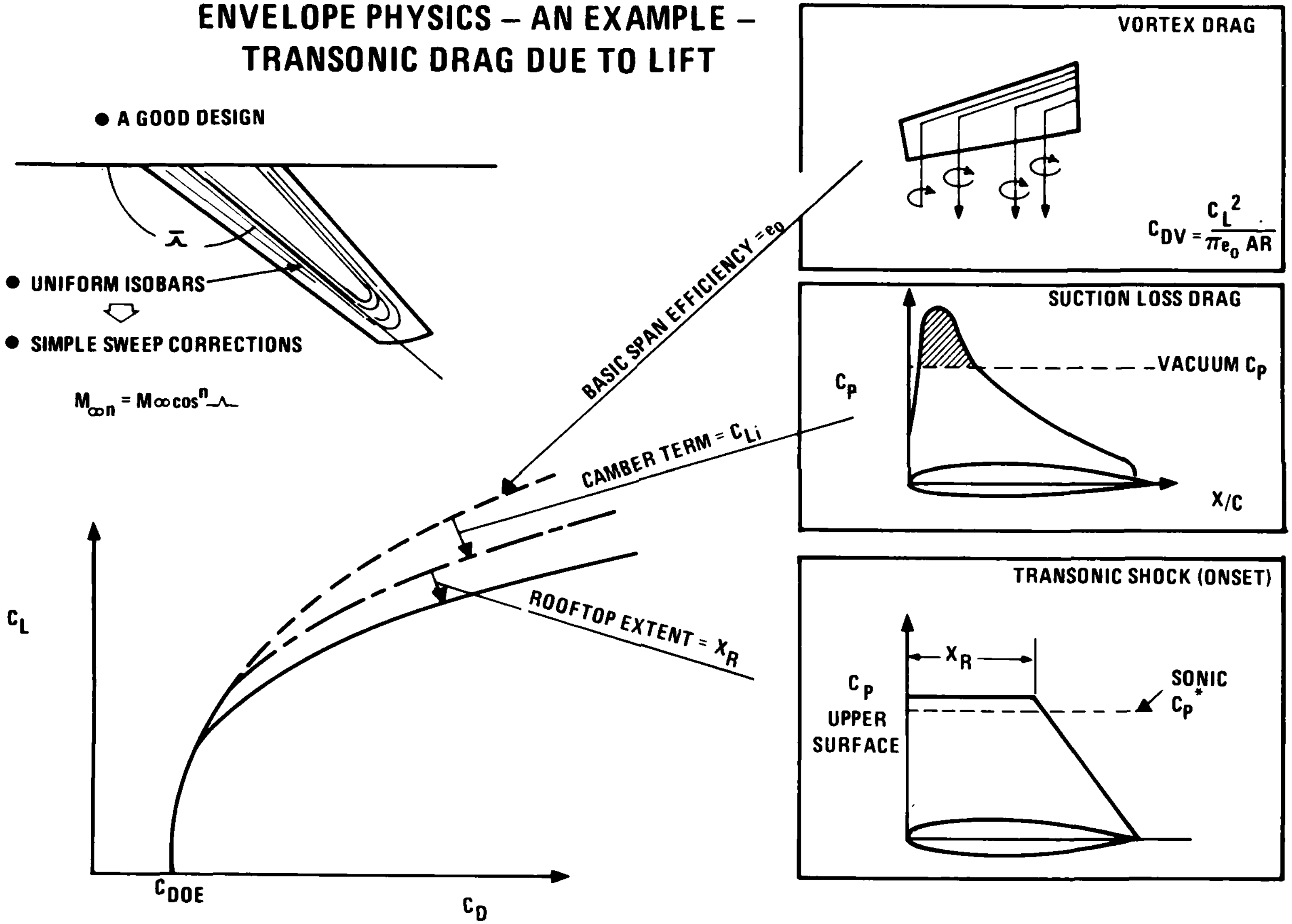
- METHODS OPTIMIZED FOR CONCEPTUAL DESIGN
- "ACCURACY" ONLY WHERE NECESSARY
  - RESOLUTION OF DIFFERENCES
  - ABSOLUTE LEVELS BY CALIBRATION TO KNOWN BASELINE
- VARIATIONS ANALYTICALLY (NOT STATISTICALLY) BASED
  - "ENVELOPE" PHYSICS
  - WELL-DESIGNED AIRPLANE
  - LEVEL-OF-EXCELLENCE PARAMETERS

⇒ CLEAR DESIGN & TECHNOLOGY QUALITY INDICATIONS

THE CONCEPTUAL DESIGN SYNTHESIS PROCEDURE



ENVELOPE PHYSICS – AN EXAMPLE – TRANSONIC DRAG DUE TO LIFT



"CALIBRATION" PARAMETERS e_0, C_{Li}, X_R EACH HAVE PHYSICAL MEANING

B27122

CDSP SUMMARY OUTPUT

SUMMARY DATA PAGE 1

	CONFIGURATION NUMBER	1	2	3	4	5	6	7	8	9	10
1	DASH MACH NUMBER	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000	1.6000
2	DASH ALTITUDE (FT)	56656.	56694.	56298.	55873.	57177.	56810.	56401.	57603.	57274.	56895.
3	DASH RADIUS (NMI)	200.	200.	200.	200.	200.	200.	200.	200.	200.	200.
4	FUSELAGE LENGTH (FT)	63.7928	63.8118	64.7491	65.9368	62.8055	63.6730	64.7438	61.9789	62.6949	63.6472
5	WING AREA (SQFT)	850.	850.	850.	850.	900.	900.	900.	950.	950.	950.
6	LE SWEEP (DEG)	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000	35.0000
7	T/C PARALLEL	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300
8	WING ASPECT RATIO	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000
9	ENGINE SCALE FACTOR	1.8000	1.8000	2.0000	2.2000	1.8000	2.0000	2.2000	1.8000	2.0000	2.2000
10	RESIZED FUS LGTH(FT)	63.7528	63.8118	64.7491	65.9368	62.8055	63.6730	64.7438	61.9789	62.6949	63.6472
11	MEAN SWEEP (DEG)	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731	24.2731
12	T/C NORMAL	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309	.0309
13	GROSS WEIGHT (LBS)	71119.	71125.	73437.	76020.	71871.	74136.	76599.	72802.	74920.	77268.
14	FUEL WEIGHT (LBS)	26646.	26647.	27380.	28339.	26960.	27654.	28509.	27427.	27999.	28755.
15	WING WEIGHT (LBS)	6852.	6893.	7014.	7147.	7224.	7347.	7478.	7563.	7681.	7812.
16	THRUST / WEIGHT T/W	.8732	.8731	.9396	.9984	.8641	.9307	.9909	.8530	.9210	.9823
17	WING LOADING W/S	83.6695	83.6764	86.3964	89.4356	79.8564	82.3739	85.1100	76.6341	78.8634	81.3346
18	MISSION RADIUS (NMI)	522.	522.	522.	522.	522.	522.	522.	522.	522.	522.
19	LOAD FACTOR 1 (G"S)	2.4924	2.4917	2.3620	2.2477	2.5705	2.4219	2.3046	2.6500	2.4915	2.3663
20	MAX LOAD FACTOR 1	8.6900	8.6872	7.5555	6.6759	9.3896	8.1020	7.1464	10.1253	8.7014	7.6483
21	TURN RATE 1 (DPS)	2.7123	2.7114	2.5423	2.3916	2.8133	2.6206	2.4668	2.9156	2.7112	2.5479
29	SPECIFIC POWER (FPS)	420.	420.	480.	536.	405.	466.	522.	390.	450.	507.
30	ACCEL TIME (SEC)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	FERRY RANGE (NMI)	2727.	2727.	2598.	2493.	2797.	2664.	2552.	2875.	2732.	2613.
32	FERRY FUEL (LBS)	30526.	30529.	33325.	36357.	29946.	32633.	35513.	29465.	32040.	34783.
33	T O OVER 50 FT (FT)	2523.	2523.	2396.	2317.	2452.	2324.	2239.	2401.	2265.	2174.
34	LAND OVER 50 FT (FT)	2654.	2654.	2727.	2807.	2577.	2646.	2720.	2510.	2574.	2642.
35	LAND OVER 50 REV(FT)	2384.	2384.	2411.	2447.	2306.	2331.	2362.	2240.	2260.	2287.
36	T O GROUND RUN (FT)	1677.	1678.	1567.	1495.	1624.	1512.	1437.	1586.	1468.	1388.
37	LAND GROUND ROLL(FT)	1922.	1922.	1984.	2050.	1862.	1920.	1982.	1810.	1863.	1921.
38	LAND GRD ROLL RV(FT)	1652.	1652.	1667.	1690.	1591.	1604.	1624.	1540.	1550.	1565.
39	TO OVR 50 TV AB(FT)	1113.	1113.	938.	810.	1057.	925.	793.	1094.	918.	784.
40	AVG UNIT PROCURE($M)	11.4760	11.4766	11.7386	11.9987	11.5331	11.7938	12.0512	11.5941	11.8508	12.1055
41	RDTE COST ($M)	2773.	2773.	2856.	2941.	2759.	2881.	2965.	2826.	2907.	2989.
42	AVE UNIT FGP 500($M)	17.0216	17.0226	17.4516	17.8798	17.1303	17.5568	17.9803	17.2461	17.6654	18.0842
43	FUEL COST ($M)	4.7747	4.7750	5.2170	5.6725	4.7400	5.1757	5.6218	4.7138	5.1411	5.5795
44	AVG LIFE CY CST ($M)	34.2804	34.2821	35.3753	36.4826	34.4079	35.4910	36.5820	34.5545	35.6187	36.6951
45	TOTAL FORCE SIZE	683.	683.	656.	630.	680.	653.	628.	676.	650.	625.
46	TO GRD RUN TV AB(FT)	754.	754.	612.	513.	742.	602.	497.	739.	597.	491.
52	LOADFACTOR T1 (G"S)	3.3886	3.3883	3.4533	3.4911	3.4541	3.5272	3.5746	3.5034	3.5946	3.6491
53	TURN RATE T1 (DPS)	6.6596	6.6590	6.7988	6.8801	6.8004	6.9575	7.0592	6.9063	7.1019	7.2185
54	LOADFACTOR T2 (G"S)	3.3886	3.3883	3.4533	3.4911	3.4541	3.5272	3.5746	3.5034	3.5946	3.6491
55	LOADFACTOR T3 (G"S)	3.6822	3.6820	3.8662	4.0074	3.6987	3.8944	4.0490	3.7010	3.9119	4.0796
56	ACCEL TIME (SEC)	76.1546	76.1527	65.5944	58.1992	79.6389	68.0826	60.0437	83.5774	70.8536	62.1014
57	MAX MACH NO.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
58	MISSION ITERATIONS	3.	4.	4.	4.	3.	4.	4.	5.	3.	3.
59	SIZING ITERATIONS	3.	4.	4.	4.	3.	4.	4.	5.	3.	3.
60	CONDITION CODE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

B42184

CDSP OUTPUT-AERODYNAMICS

AERODYNAMIC CHARACTERISTICS

CD MIN SUBSONIC= .01059
K SUBSONIC= .14275
L/D MAX SUBSONIC= 12.85692
CL AT MAX SUBSONIC L/D= .27263
CRUISE MACH= .85984
CRUISE CL= .24223
CRUISE L/D= 12.7687
MAX SUBSONIC CL AT .8M= .56476
SUPERSONIC TRIM DRAG FACTOR= 1.0900
MAX WING MIN-WAVE-DRAG MACH= 1.20

AERODYNAMICS OPTION 6.

DRAG POLARS CD=CDOE+CDL (ADD COST FOR STORES-IN) CDL=CDI+CDP+CDR

MACH = .300 CDOF = .0106 K = .1427

CL	CD	CDL	COST	CDI	CDP	CDR	MDD
0.00000	.01059	0.00000	.00121	0.00000	0.00000	0.00000	.92474
.10000	.01202	.00142	.00121	.00141	.00001	0.00000	.93734
.20000	.01630	.00570	.00121	.00566	.00004	0.00000	.38337
.30000	.02347	.01287	.00121	[illegible]	[illegible]	0.00000	[illegible]

MACH = 1.200 CDOF = .0219 K = .2328

CL	CD	CDL	COST
0.00000	.02191	0.00000	.00253
.10000	.02424	.00233	.00253
.20000	.03123	.00931	.00253
.30000	.04287	.02095	.00253
.40000	.05917	.03725	.00253
.50000	.08012	.05821	.00253
.60000	.10573	.08382	.00253
.70000	.13600	.11408	.00253
.80000	.17092	.14901	.00253
.90000	.21050	.18859	.00253

MA

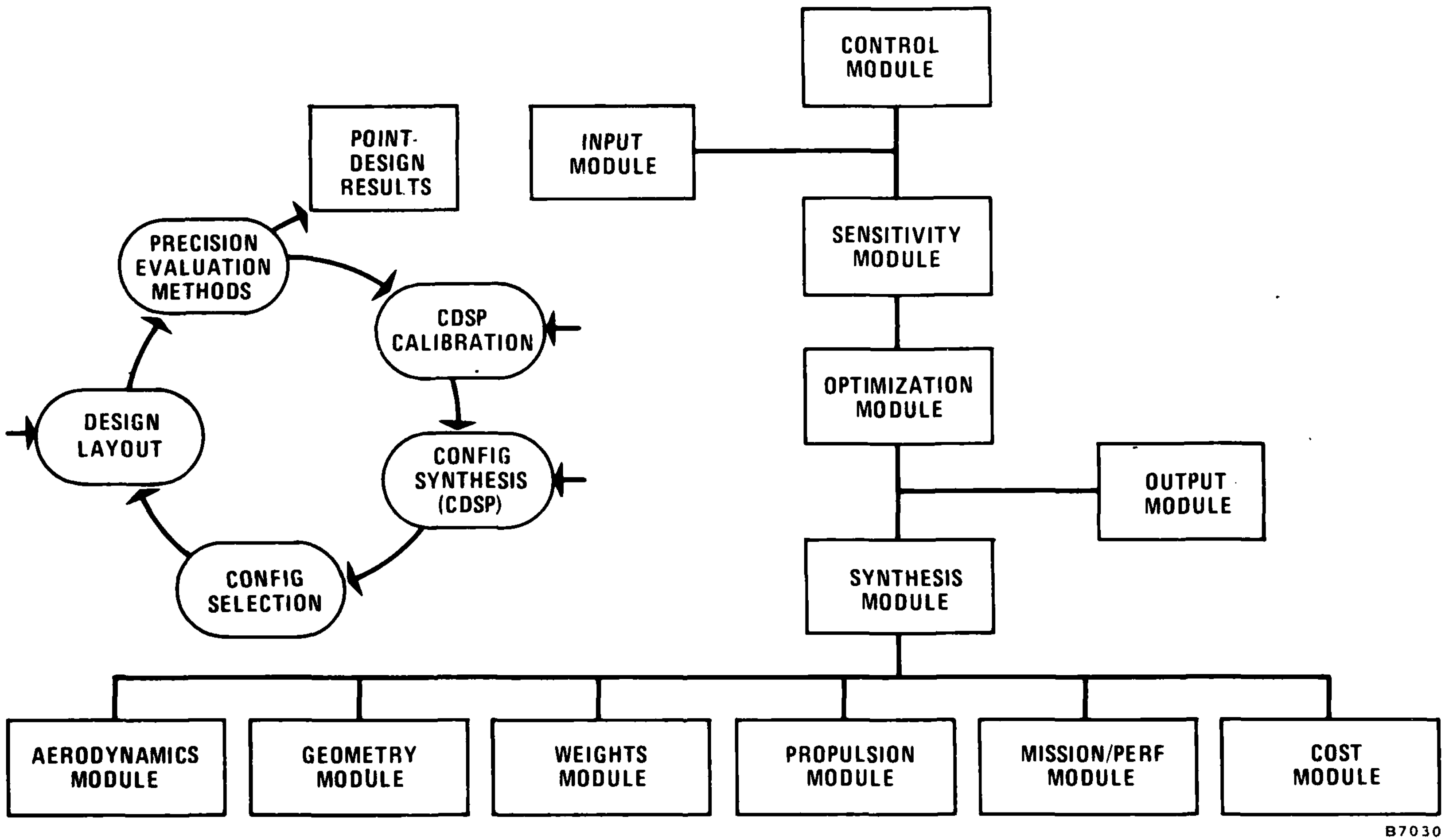
MAC

MINIMUM DRAG DATA CDM=CDF+CDEX+CDWAVE (CDWAVE=CDWWG+CDWN+CDWF)

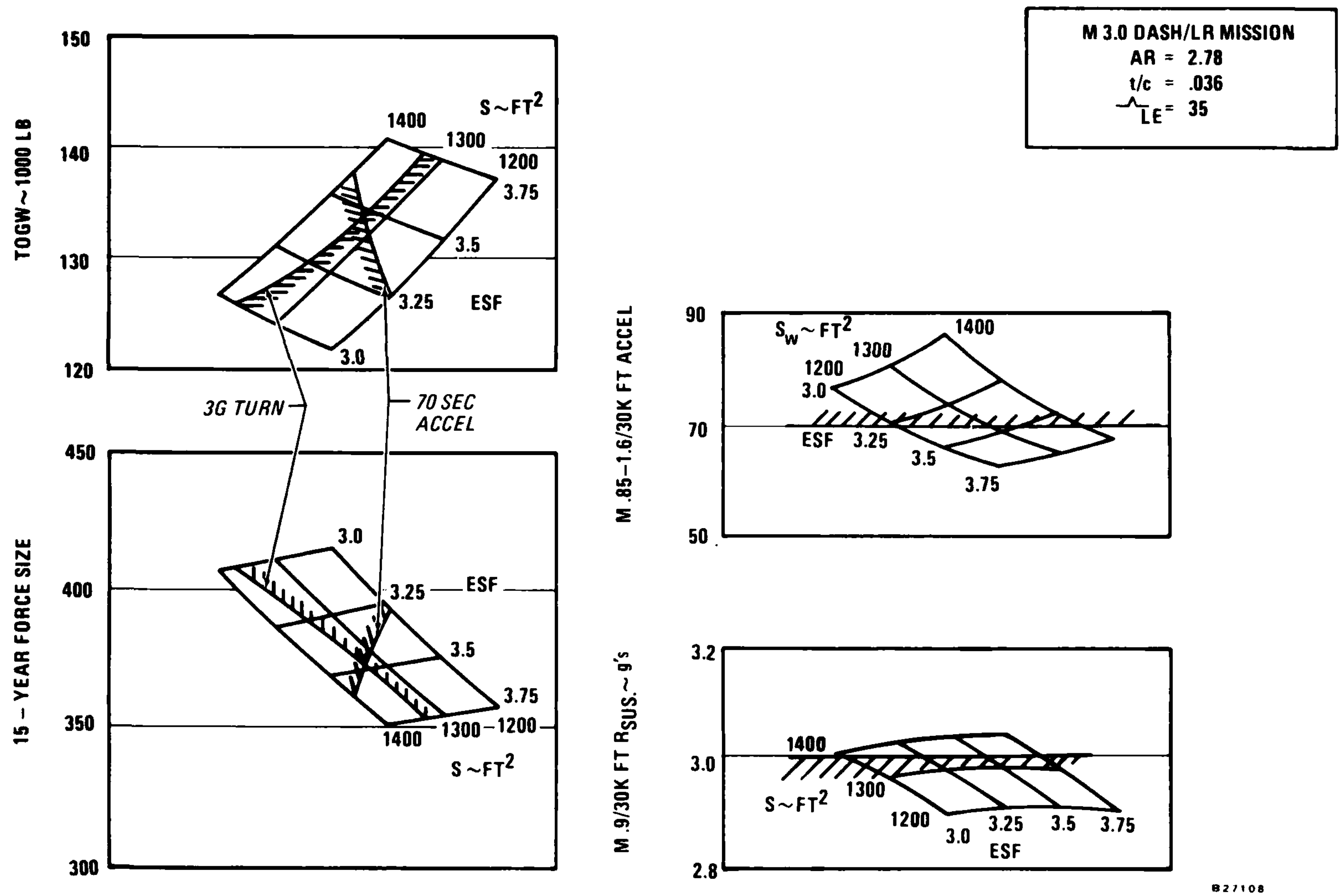
MACH	CDM	CDF	CDEX	COSTORE	CDWAVE	CDWWG	CDWN	CDWF	CLP	CDOF	K
.3000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6368	.0106	.1427
.4000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6495	.0106	.1427
.5000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6299	.0106	.1427
.6000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6388	.0106	.1427
.7000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.6854	.0106	.1427
.8000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.7878	.0106	.1427
.9000	.0106	.0096	0.0000	.0012	0.0000	0.0000	0.0000	0.0000	.8022	.0106	.1427
1.0000	.0164	.0106	0.0000	.0012	.0058	0.0000	0.0000	0.0000	.8022	.0164	.1427
1.1000	.0216	.0104	0.0000	.0025	.0112	.0086	0.0000	.0026	.8022	.0216	.2157
1.2000	.0219	.0103	0.0000	.0025	.0115	.0089	0.0000	.0026	.8022	.0219	.2328
1.3000	.0249	.0101	0.0000	.0025	.0149	.0095	.0027	.0026	.8022	.0249	.2519
1.4000	.0240	.0100	0.0000	.0025	.0141	.0085	.0030	.0026	.8022	.0240	.2708
1.5000	.0231	.0098	0.0000	.0025	.0133	.0074	.0033	.0026	.8022	.0231	.2907
1.6000	.0226	.0096	0.0000	.0025	.0129	.0069	.0035	.0026	.8022	.0226	.3117
1.7000	.0221	.0095	0.0000	.0024	.0126	.0063	.0037	.0026	.8022	.0221	.3335
1.8000	.0217	.0093	0.0000	.0024	.0123	.0059	.0039	.0026	.8022	.0217	.3559
1.9000	.0212	.0092	0.0000	.0024	.0121	.0055	.0040	.0026	.8022	.0212	.3790
2.0000	.0209	.0090	0.0000	.0024	.0119	.0051	.0042	.0026	.8022	.0209	.4010

5B9428A

TYPICAL AIRCRAFT SYNTHESIS COMPUTATIONAL MODULES

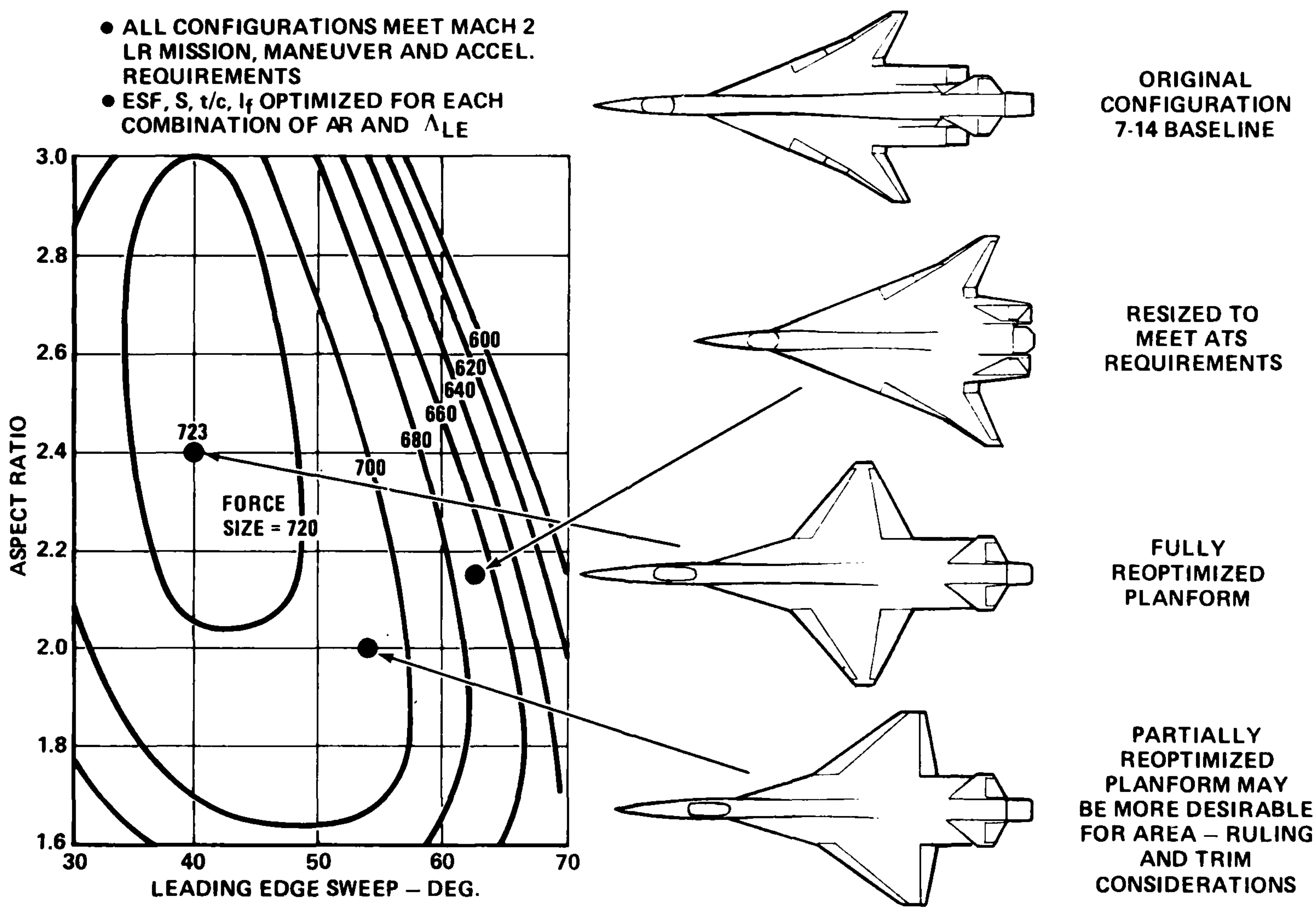


TYPICAL CONFIGURATION SELECTION
CARPET PLOTS –
WING AREA/ENGINE–SCALE TRADES



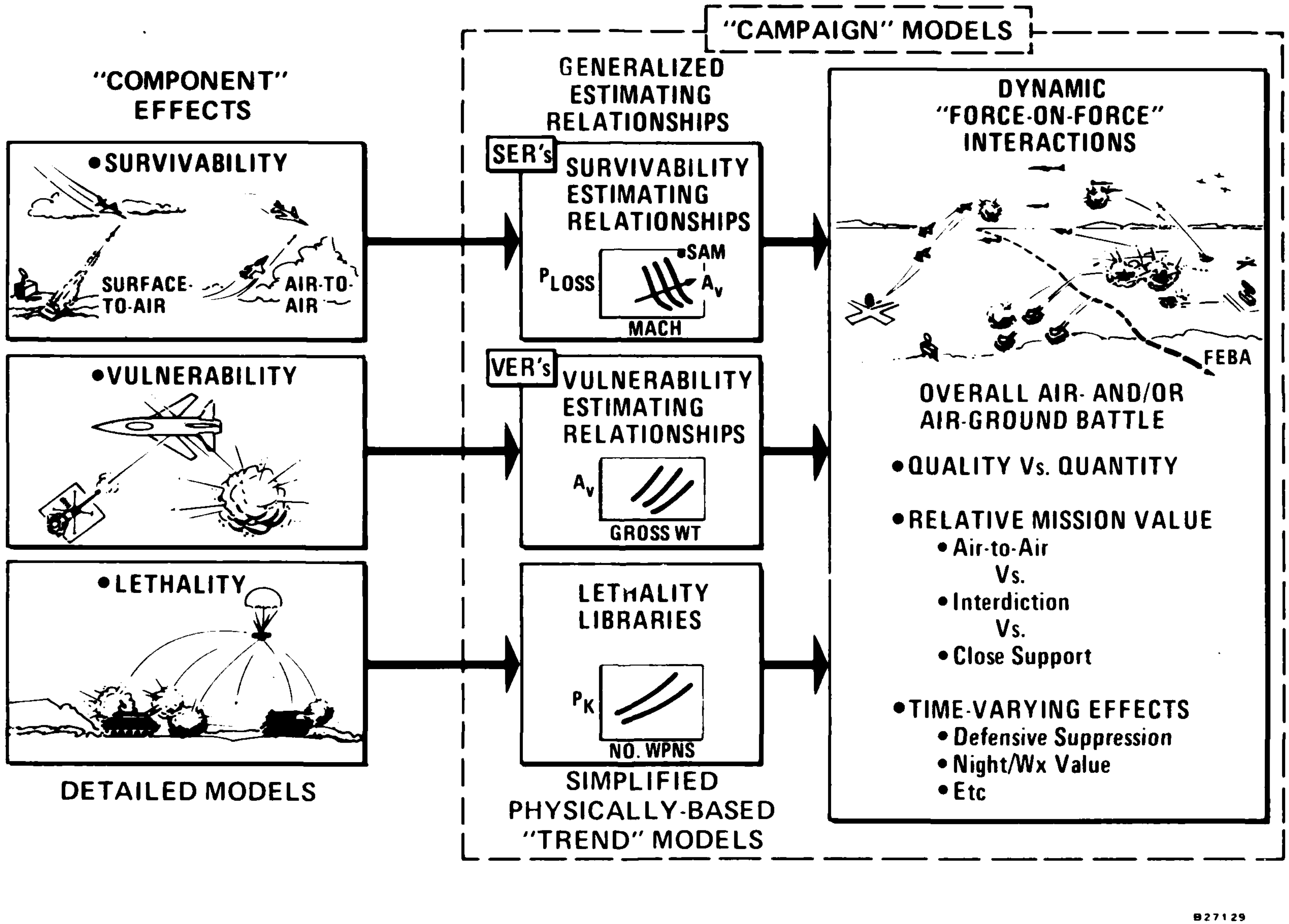
CONFIGURATION OPTIMIZATION – THE ANSWERS AREN'T SACRED

- ALL CONFIGURATIONS MEET MACH 2 LR MISSION, MANEUVER AND ACCEL. REQUIREMENTS
- ESF, S, t/c, l_f OPTIMIZED FOR EACH COMBINATION OF AR AND Λ_{LE}



6B2026B

EFFECTIVENESS – BUILDING UP THE WHOLE PICTURE



OVERVIEW OF CAD EFFORTS AT GRUMMAN

Alfred Vachris
RAVES Project Manager
Grumman Aerospace
Bethpage, New York

OVERVIEW OF CAD EFFORTS AT GRUMMAN

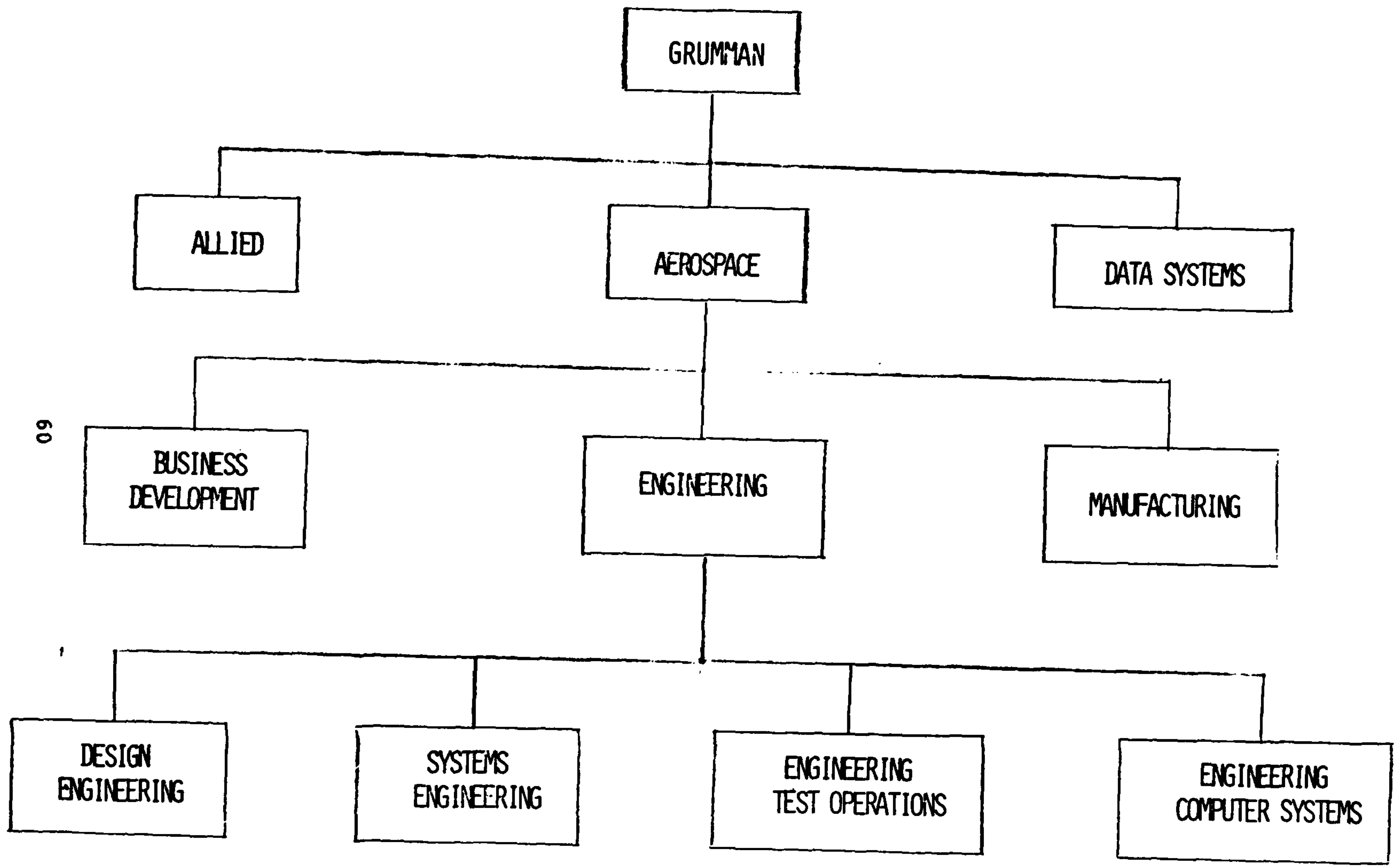
Alfred Vachris
RAVES Project Manager
Grumman Aerospace
Bethpage, New York

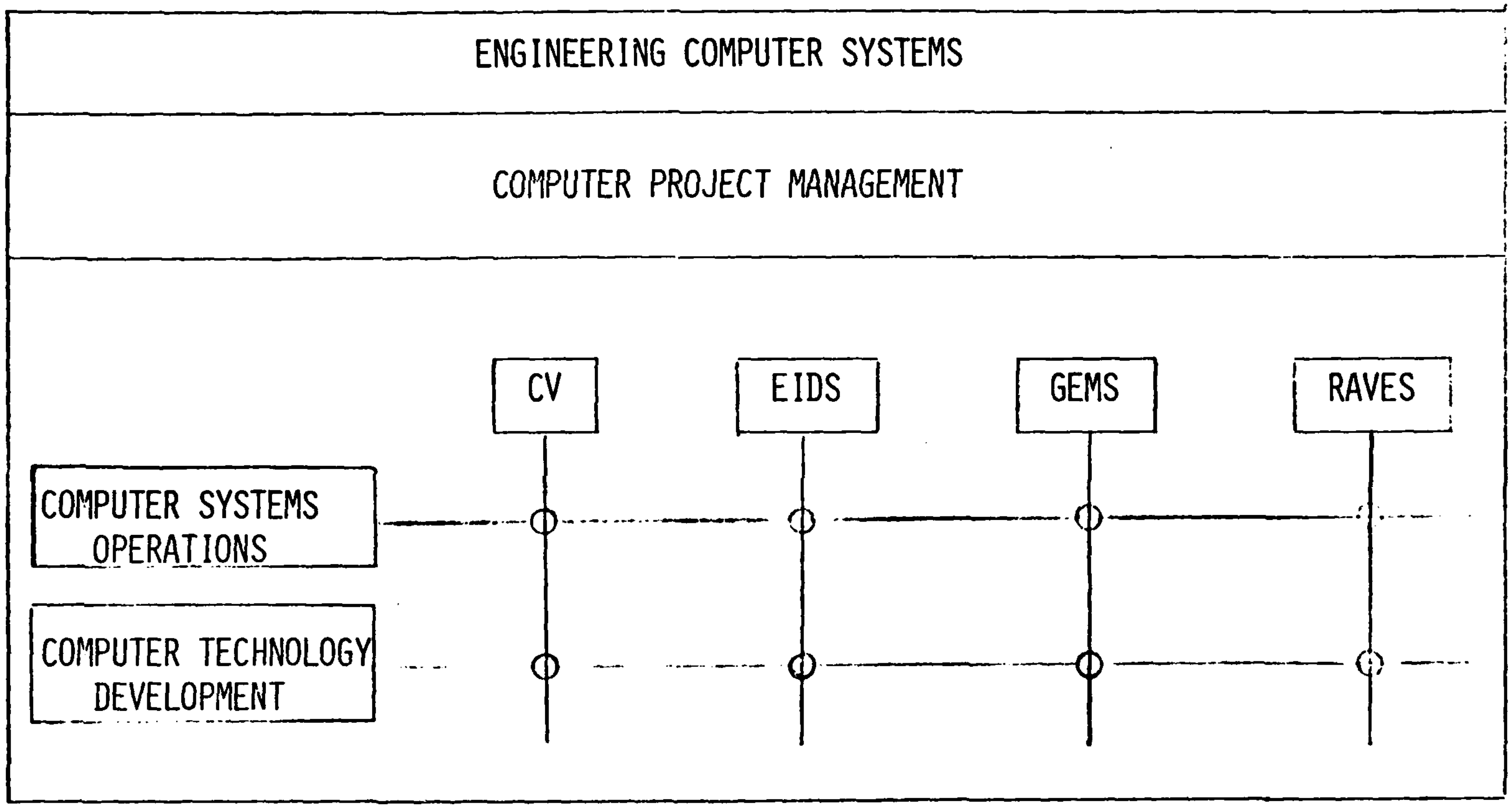
This paper presents an outline of the various CAD efforts that Grumman has evolved while building the Rapid Aerospace Vehicle Evaluation System (RAVES) and the Grumman Engineering Manufacturing System (GEMS), which have been developed during the last 10 years. Current efforts are to form an integration system, which will build a bridge from preliminary design to engineering to manufacturing. The system will outline the needs of vulnerability assessment and the broad-based requirement for a total 3D model of aircraft geometry, both internal and external. To accomplish the development of such a model as well as the ability to store and to use such a model will require a very sophisticated data base management capability. The paper concludes with a review of various modeling techniques.

COMPUTER AIDED DESIGN

AT GRUMMAN

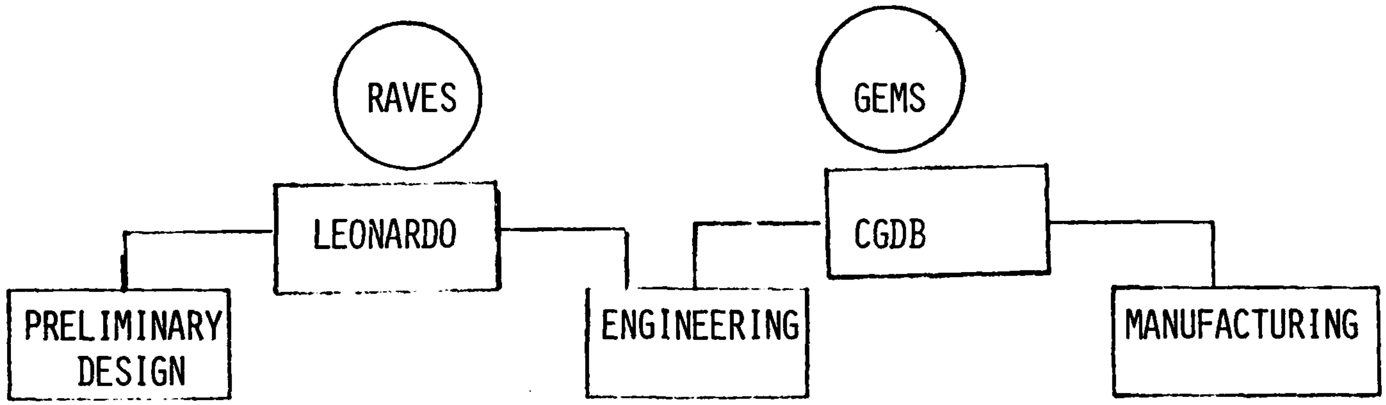
ALFRED VACHRIS
RAVES PROJECT
GRUMMAN AEROSPACE


GRUMMAN
ALLIED
AEROSPACE
DATA SYSTEMS
BUSINESS DEVELOPMENT
ENGINEERING
MANUFACTURING
DESIGN ENGINEERING
SYSTEMS ENGINEERING
ENGINEERING TEST OPERATIONS
ENGINEERING COMPUTER SYSTEMS



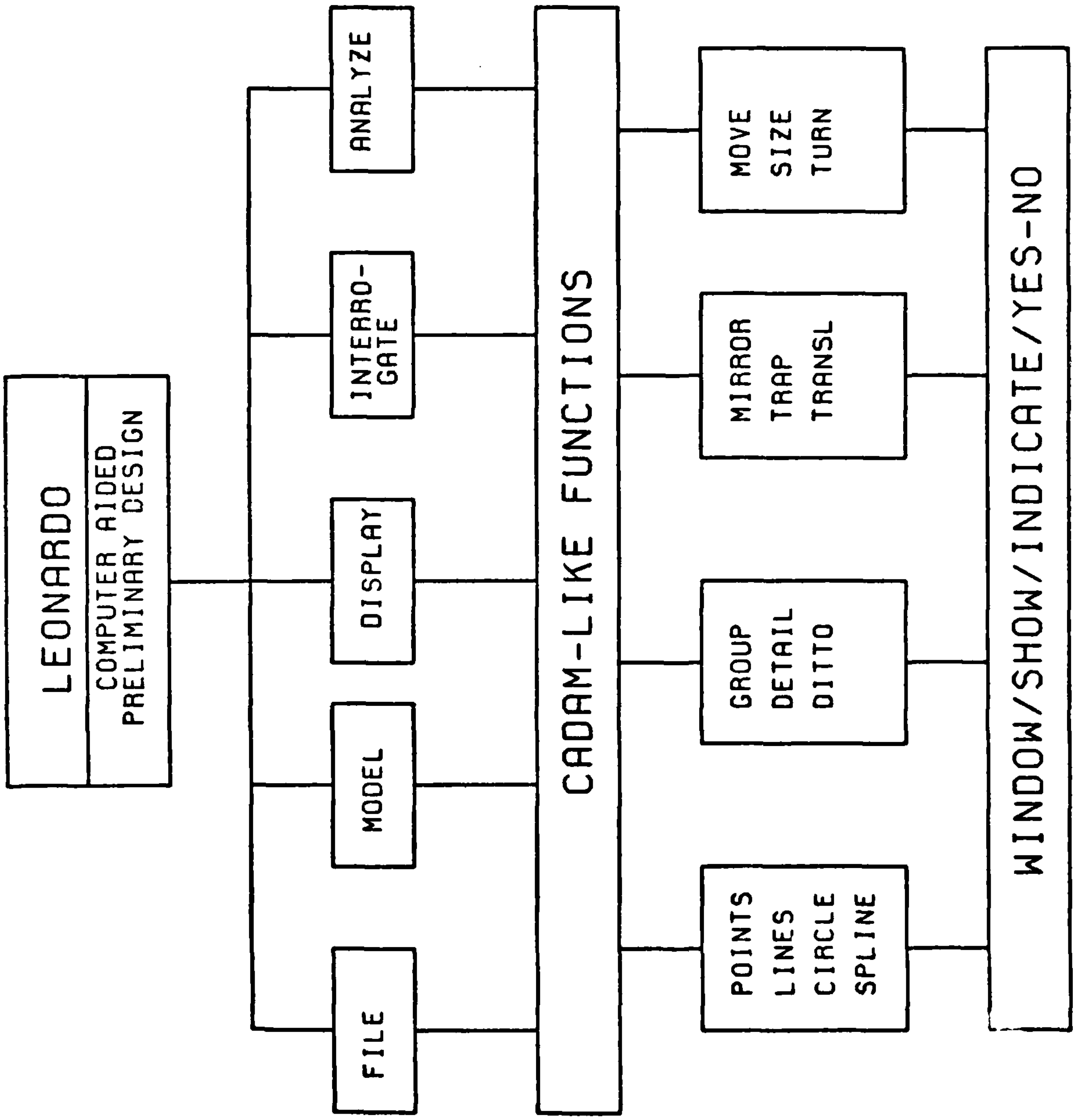
CV - COMPUTER VISION
EIDS - END ITEM DEFINITION SYSTEM
GEMS - GRUMMAN ENGINEERING MANUFACTURING SYSTEM
RAVES - RAPID AEROSPACE VEHICLE EVALUATION SYSTEM

CURRENT CAD PROJECTS

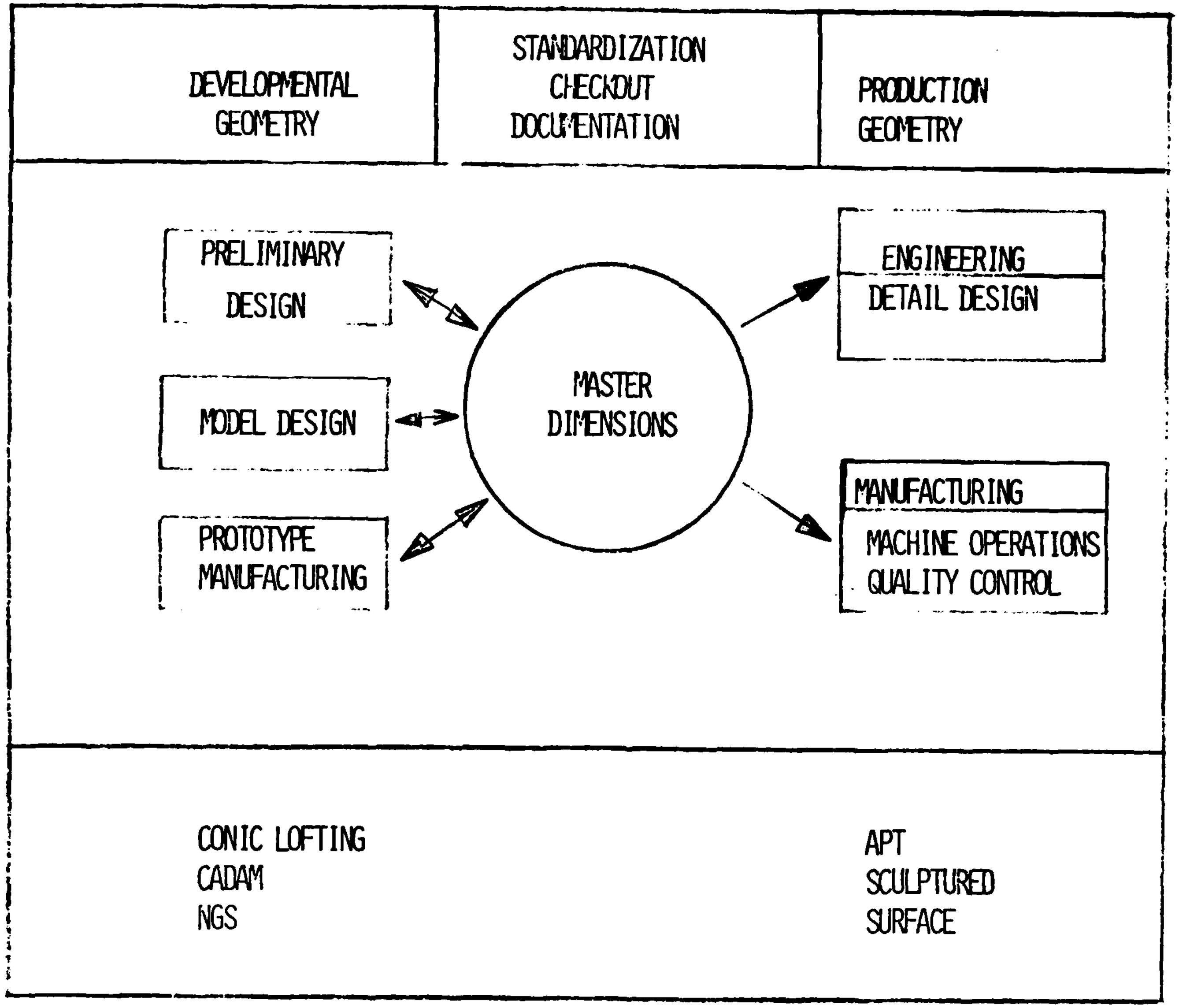


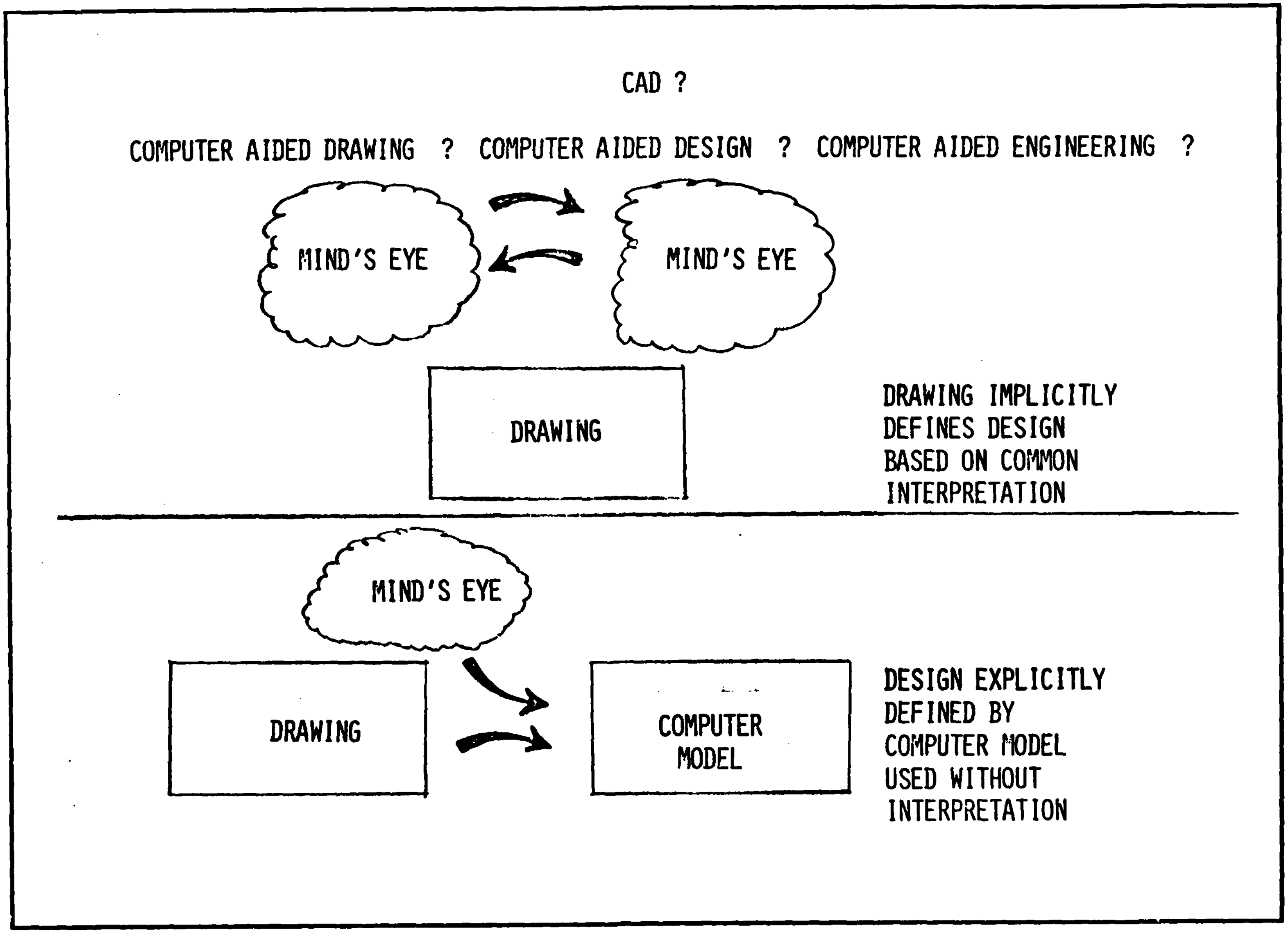
LEONARDO -- CONFIGURATION DESIGN SYSTEM

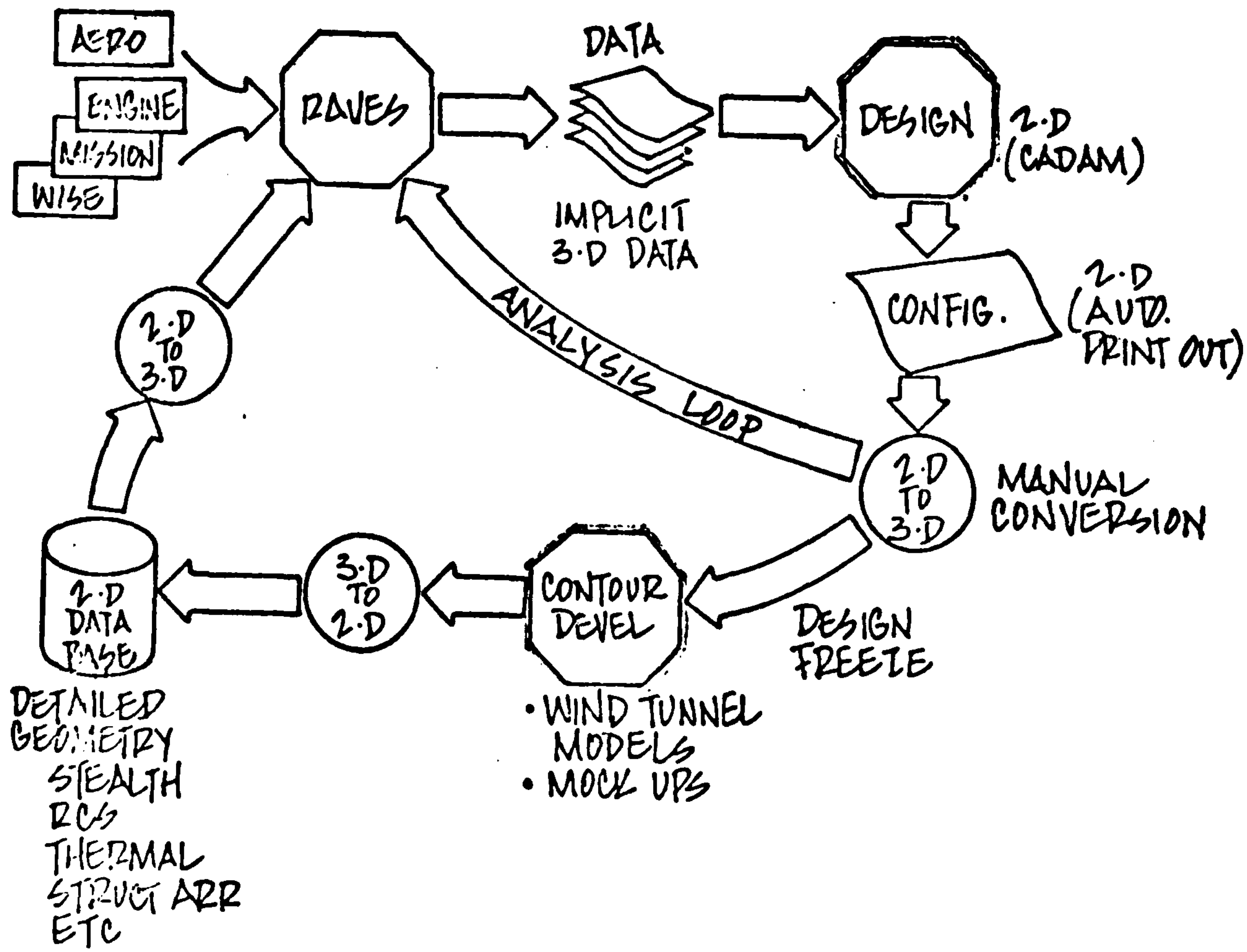
CGDB -- CORPORATE GEOMETRY DATA BANK

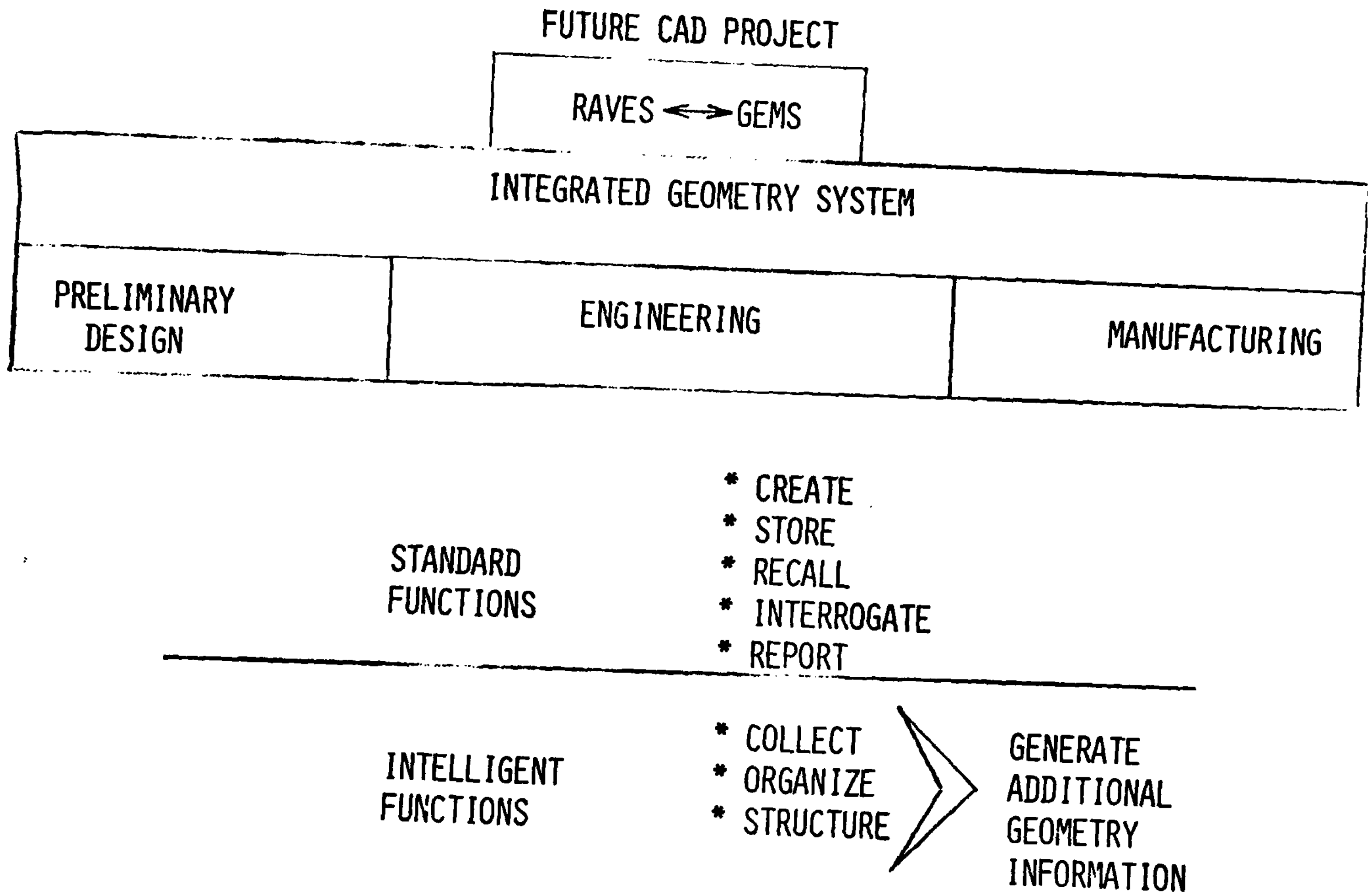

LEONARDO
COMPUTER AIDED PRELIMINARY DESIGN
FILE
MODEL
DISPLAY
INTERRO-GATE
ANALYZE
CADAM-LIKE FUNCTIONS
POINTS LINES CIRCLE SPLINE
GROUP DETAIL DITTO
MIRROR TRAP TRANSL
MOVE SIZE TURN
WINDOW/SHOW/INDICATE/YES-NO

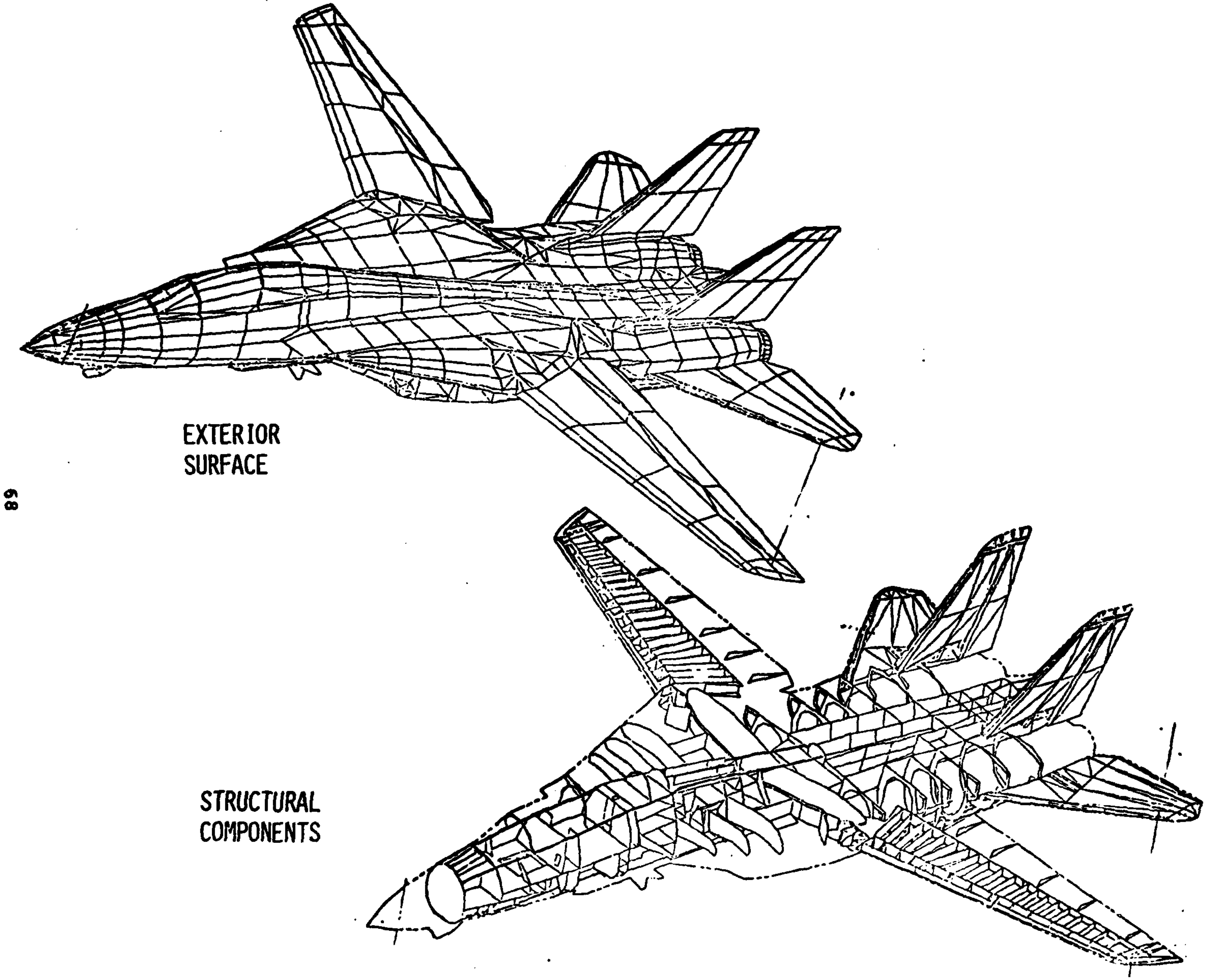
CORPORATE GEOMETRY DATA BANK

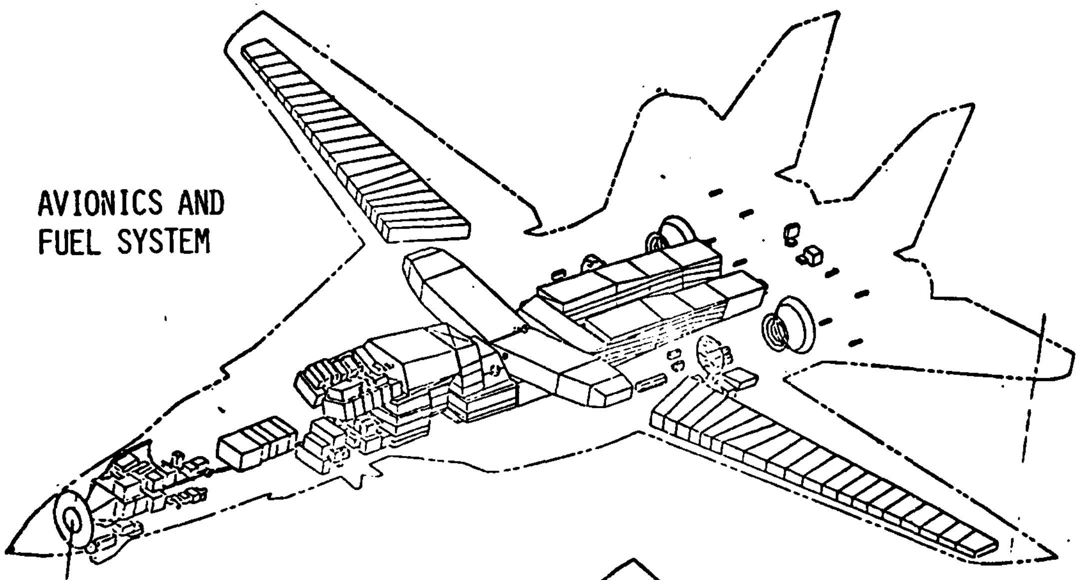


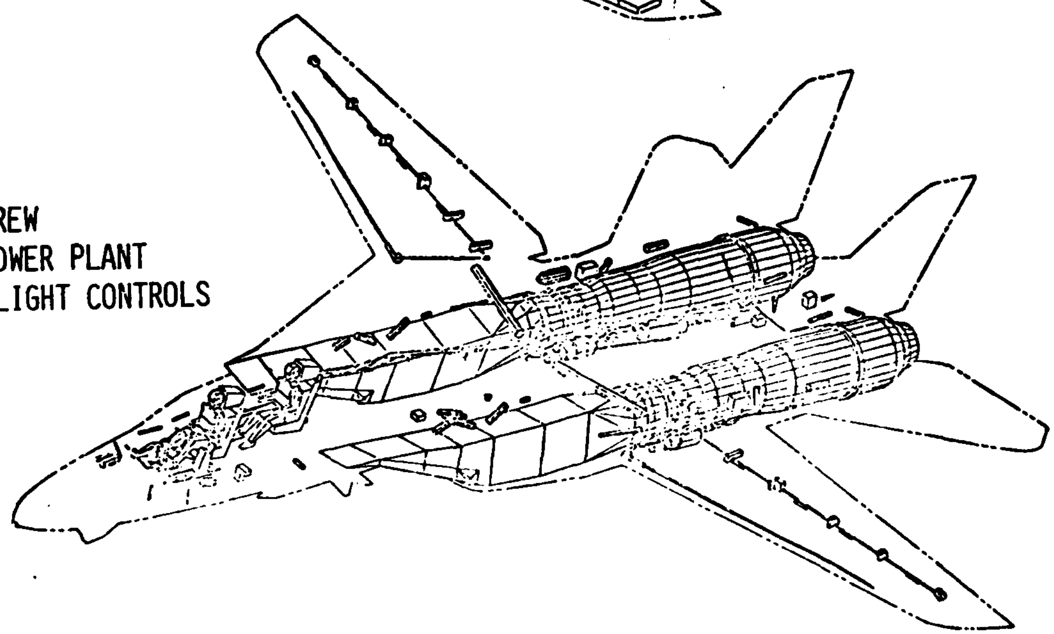

CAD ?
COMPUTER AIDED DRAWING ? COMPUTER AIDED DESIGN ? COMPUTER AIDED ENGINEERING ?
MIND'S EYE
MIND'S EYE
DRAWING
DRAWING IMPLICITLY DEFINES DESIGN BASED ON COMMON INTERPRETATION
MIND'S EYE
DRAWING
COMPUTER MODEL
DESIGN EXPLICITLY DEFINED BY COMPUTER MODEL USED WITHOUT INTERPRETATION


AERO
ENGINE
MISSION
WISE
RAVES
DATA
IMPLICIT
3·D DATA
DESIGN
2·D
(CADAM)
CONFIG.
2·D
(AUTO.
PRINT OUT)
2·D
TO
3·D
MANUAL
CONVERSION
ANALYSIS LOOP
DESIGN
FREEZE
CONTOUR
DEVEL
• WIND TUNNEL
MODELS
• MOCK UPS
3·D
TO
2·D
2·D
DATA
BASE
DETAILED
GEOMETRY
STEALTH
RCS
THERMAL
STRUCT ARR
ETC
2·D
TO
3·D

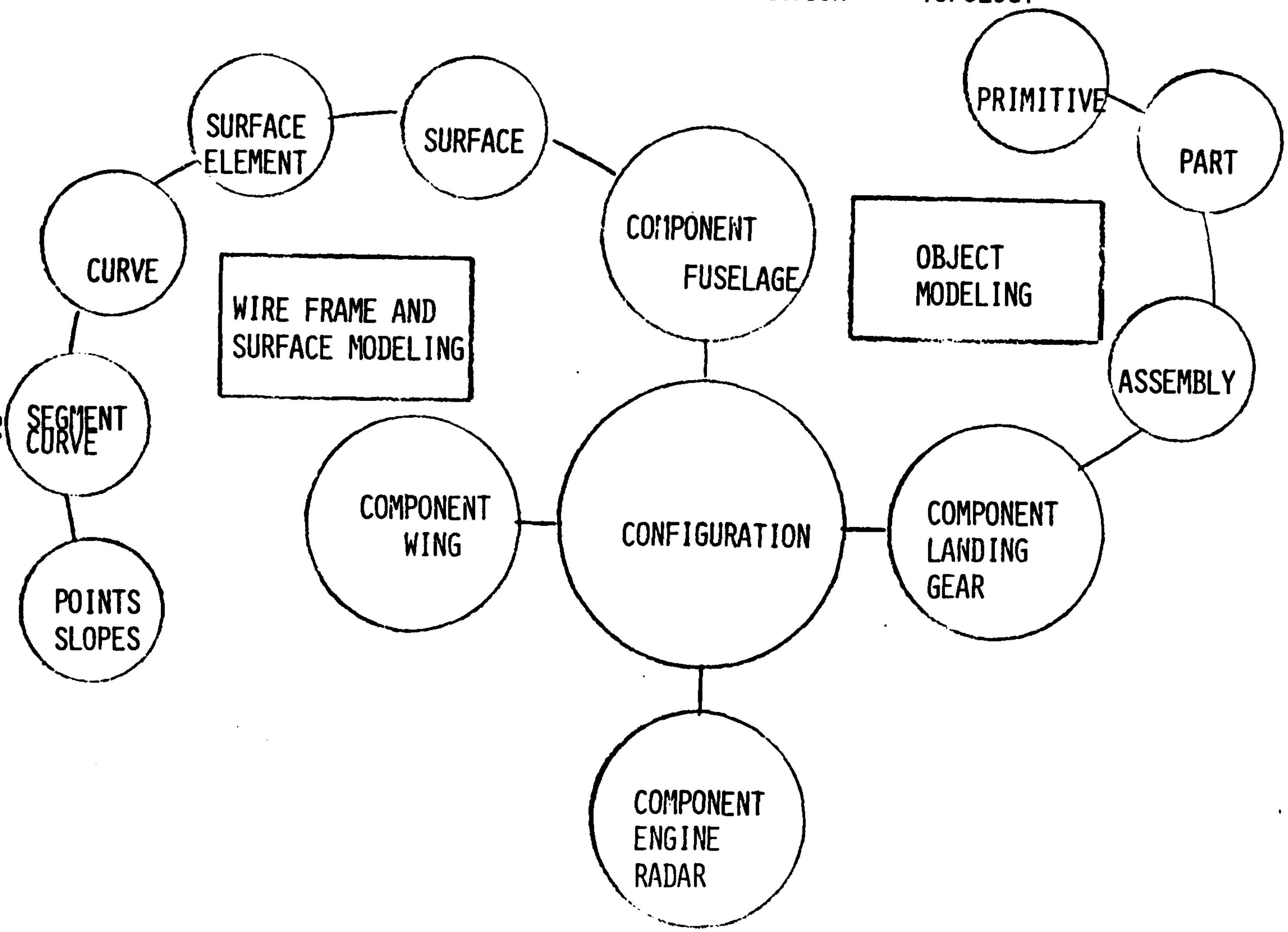

FUTURE CAD PROJECT
RAVES ⟷ GEMS
INTEGRATED GEOMETRY SYSTEM
PRELIMINARY DESIGN
ENGINEERING
MANUFACTURING
STANDARD FUNCTIONS
* CREATE
* STORE
* RECALL
* INTERROGATE
* REPORT
INTELLIGENT FUNCTIONS
* COLLECT
* ORGANIZE
* STRUCTURE
GENERATE ADDITIONAL GEOMETRY INFORMATION


EXTERIOR
SURFACE
STRUCTURAL
COMPONENTS

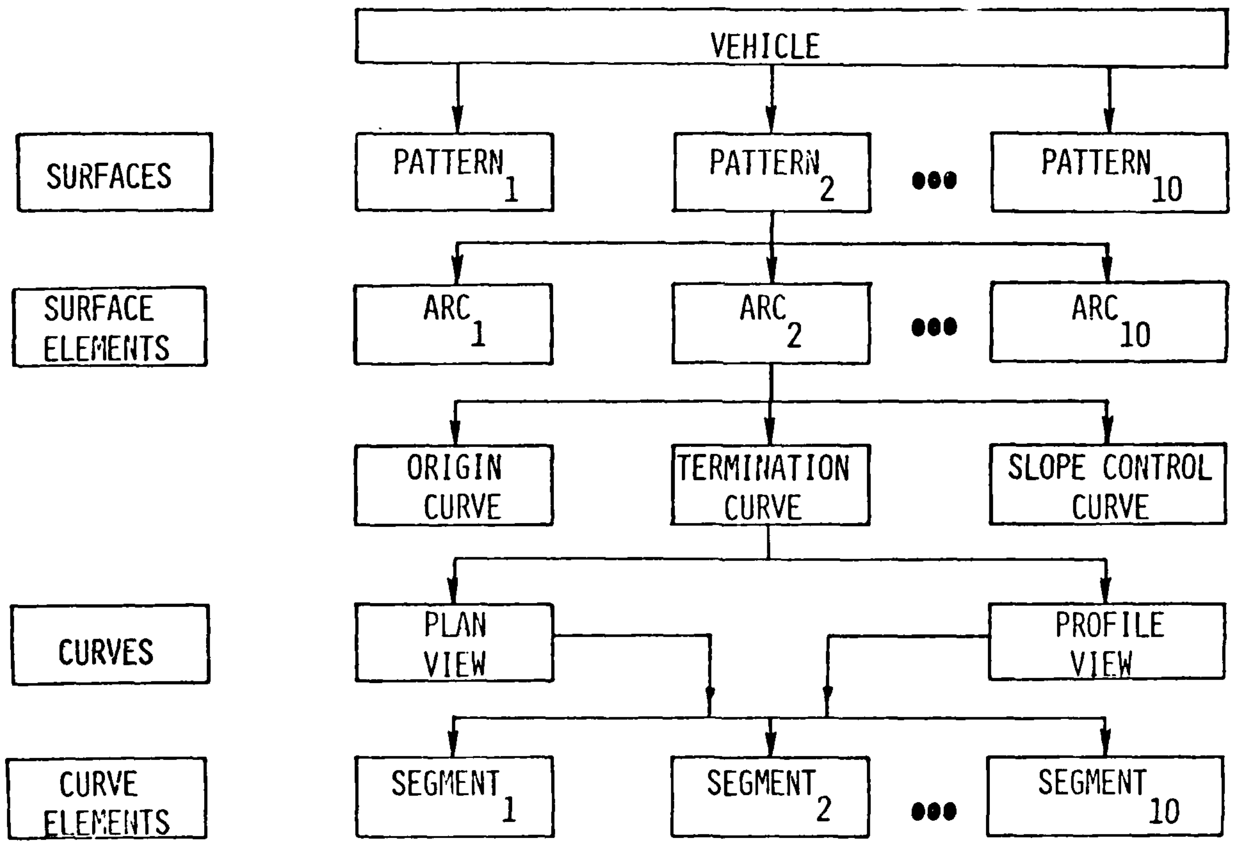

AVIONICS AND
FUEL SYSTEM


CREW
POWER PLANT
FLIGHT CONTROLS

GEOMETRIC ORGANIZATION OF A CONFIGURATION = TOPOLOGY



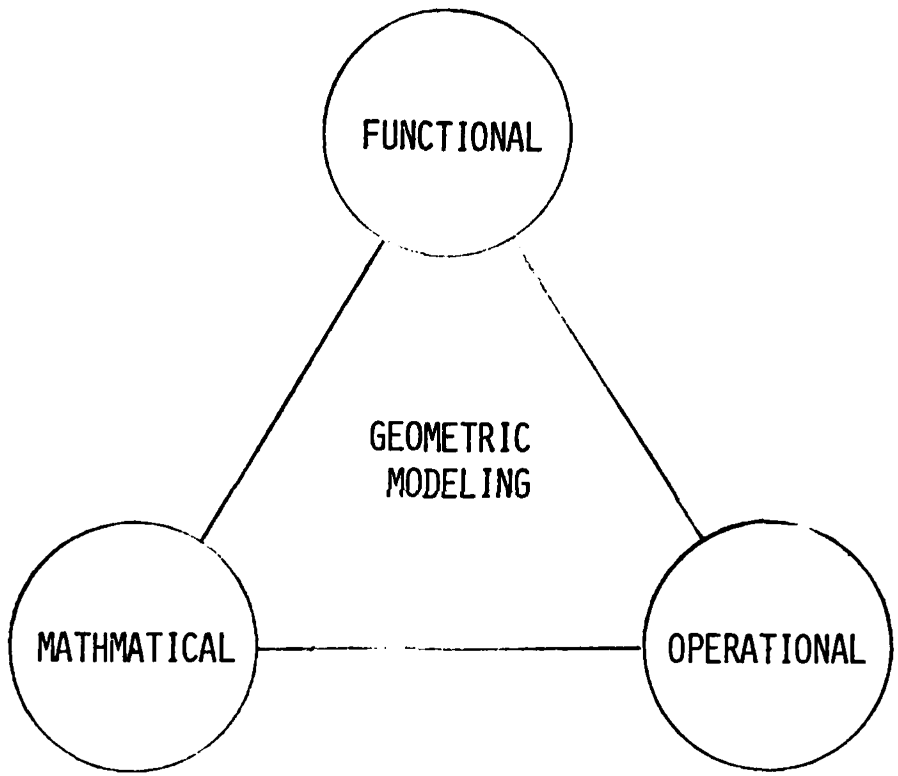
DATA STRUCTURE



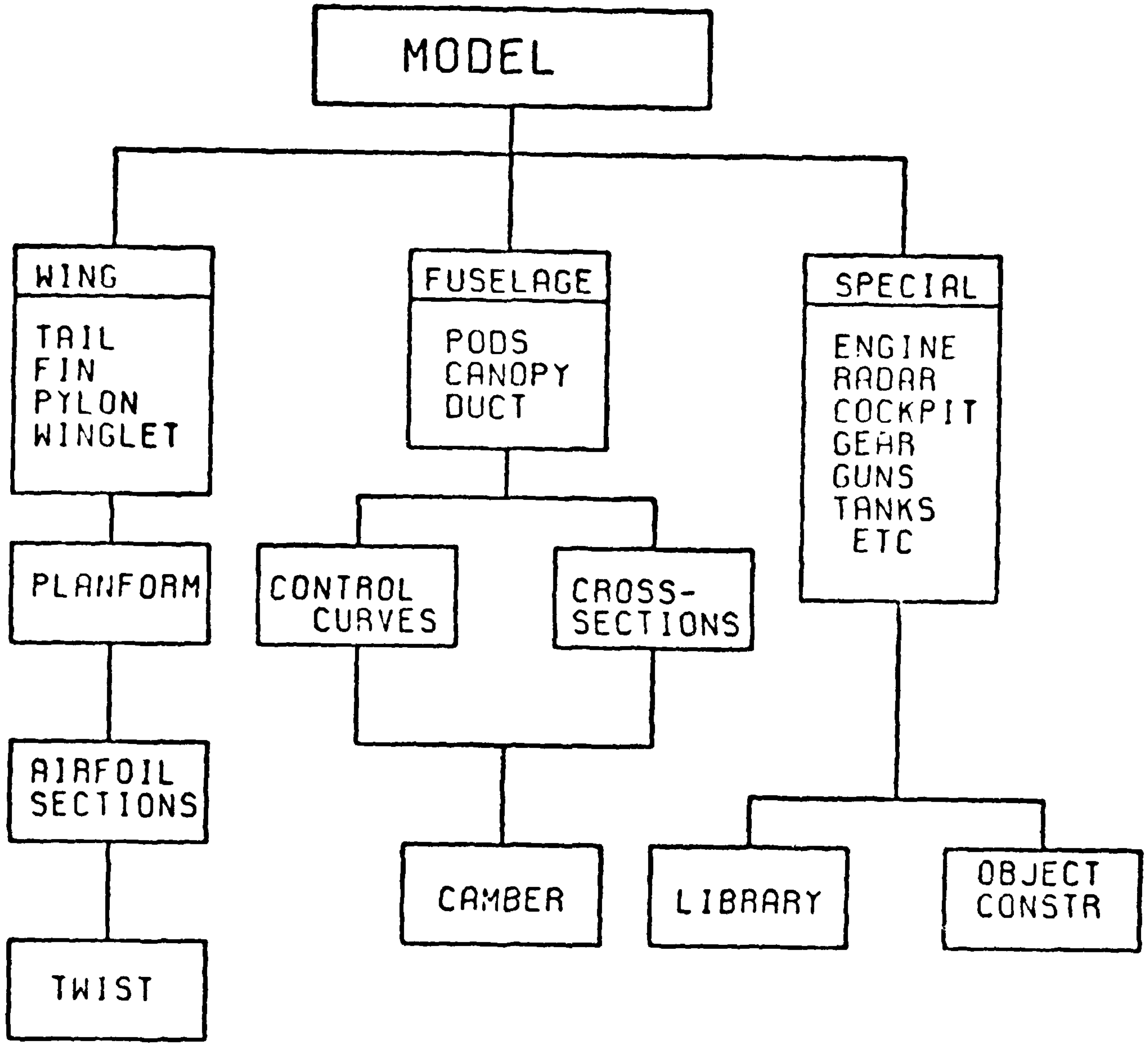
GRUMMAN

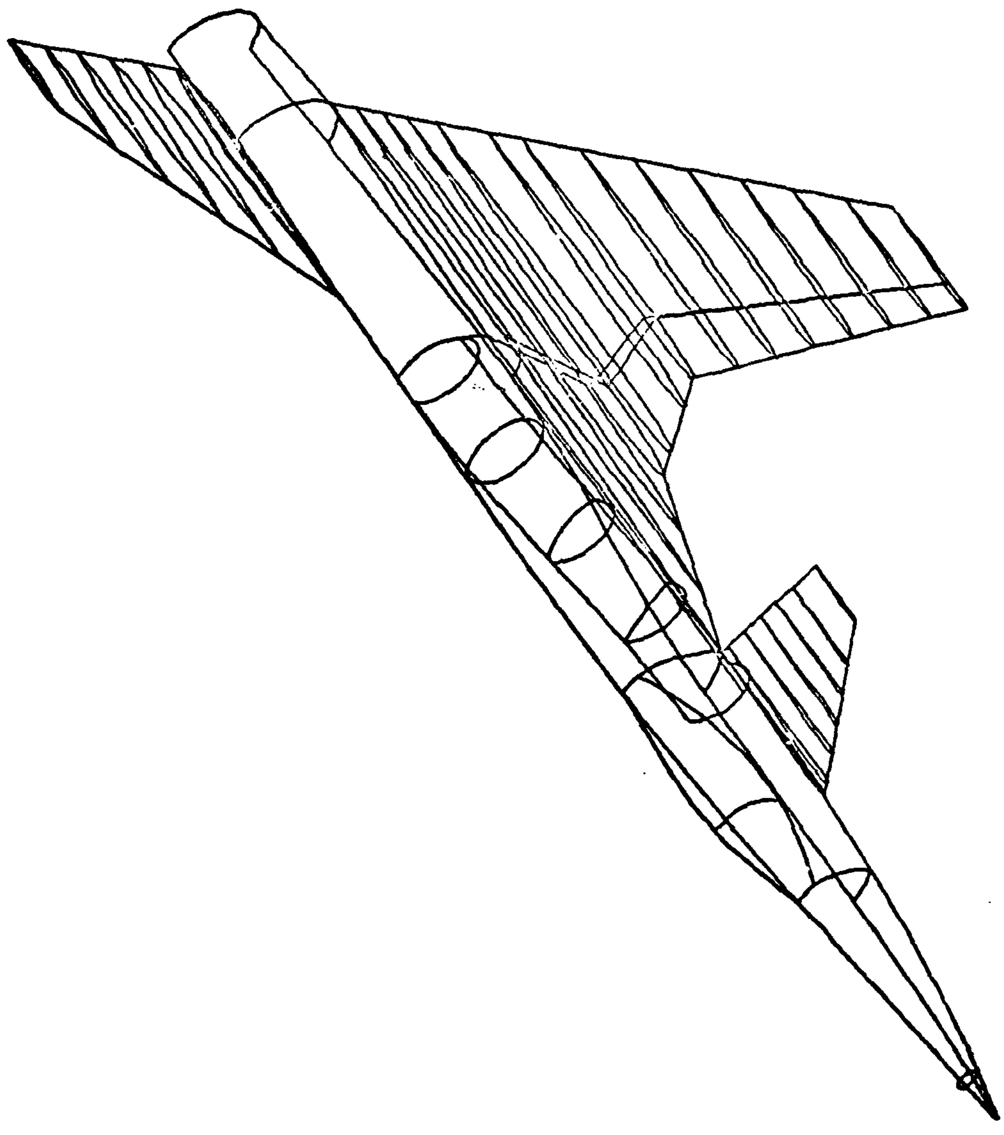
TOPOLOGY

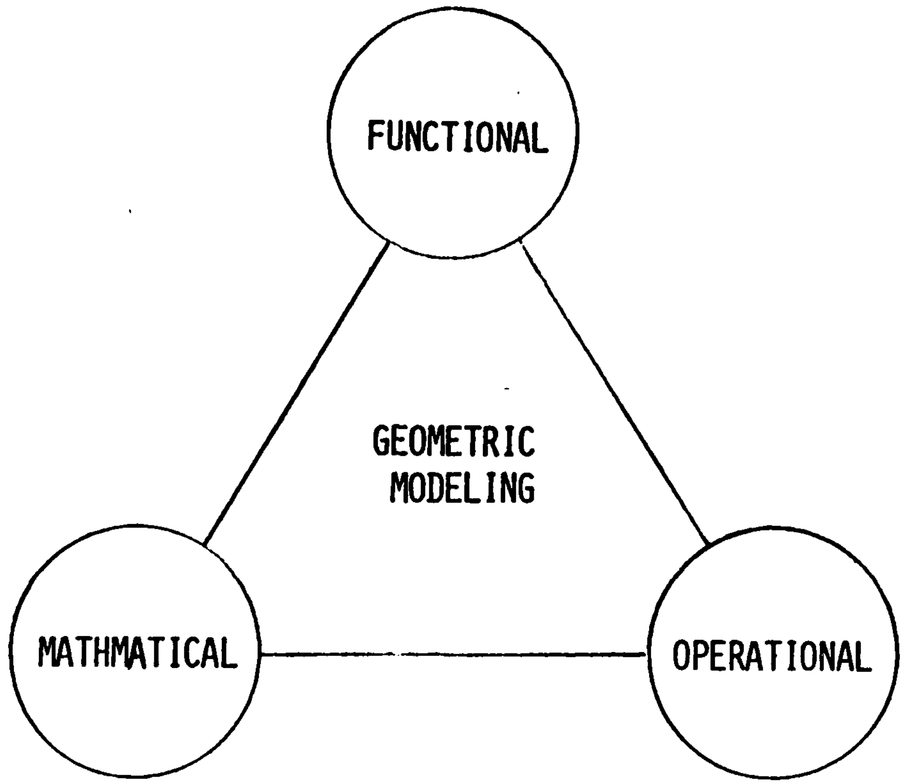
* COLLECT ELEMENTS TO FORM NEW ELEMENTS
  - DEVELOP AND RECORD CONNECTIVITY
  - BUILD A CURVE FROM CURVE SEGMENTS
* COLLECT ELEMENTS INTO FUNCTIONAL GROUPS
  - DEVELOP AND RECORD PARENT - CHILD RELATIONSHIPS
  - FORM A SURFACE FROM BOUNDARY CURVES
* DEFINE PARAMETRIC GEOMETRY
  - CHANGE IN GEOMETRY IS EQUIVALENT TO A CHANGE IN PARAMETERS
* RELATE DATA TO GEOMETRIC ELEMENTS
  - DEFINE ATTRIBUTES



FUNCTIONAL - FUSELAGE/WING/SPECIAL COMPONENTS
MATHEMATICAL - WIRE FRAME/SURFACE/OBJECT
OPERATIONAL - MOLD/BLEND/ASSEMBLE/SUB-DIVIDE


MODEL
WING
TAIL
FIN
PYLON
WINGLET
FUSELAGE
PODS
CANOPY
DUCT
SPECIAL
ENGINE
RADAR
COCKPIT
GEAR
GUNS
TANKS
ETC
PLANFORM
CONTROL CURVES
CROSS-SECTIONS
AIRFOIL SECTIONS
CAMBER
LIBRARY
OBJECT CONSTR
TWIST

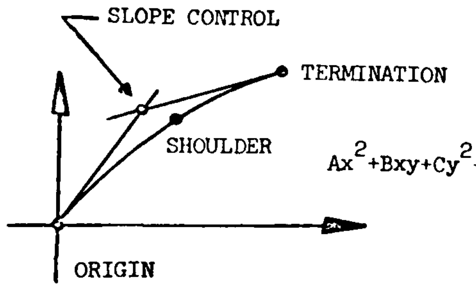




FUNCTIONAL	-	FUSELAGE/WING/SPECIAL COMPONENTS
MATHEMATICAL	-	WIRE FRAME/SURFACE/OBJECT
OPERATIONAL	-	MOLD/BLEND/ASSEMBLE/SUB-DIVIDE

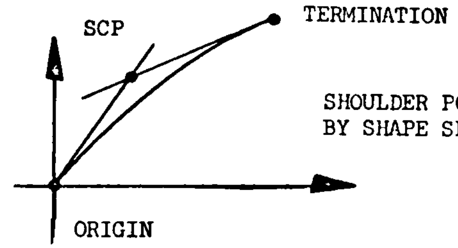
CURVE ELEMENT DEFINITION

STANDARD LOFTING CONIC



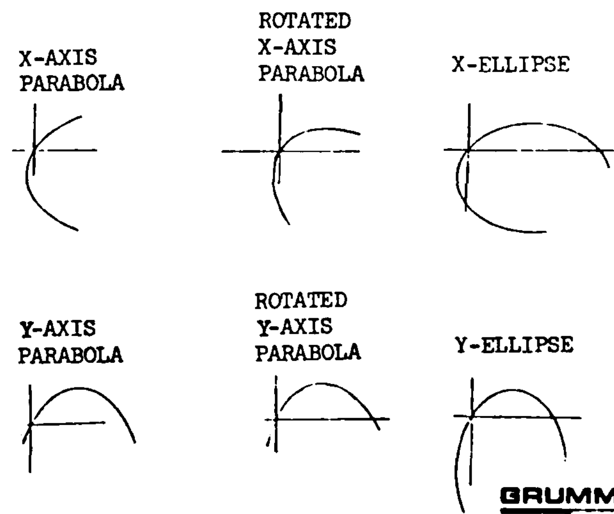
$Ax^2+Bxy+Cy^2+Dx+Ey = 0$

QUICK CURVE SEGMENT



SHOULDER POINT IS REPLACED BY SHAPE SPECIFICATION

SHAPE	KEYWORD	EQUATION
Line	LINE	$Ax+By = 0$
x-Parabola	XPAR	$Ax+By+y^2 = 0$
y-Parabola	YPAR	$Ax+By+x^2 = 0$
Rotated x-Parabola	RXPA	$Ax+By+Cxy+y^2 = 0$
Rotated y-Parabola	RYPA	$Ax+By+Cxy+x^2 = 0$
x-Ellipse	ELLX	$Ax+By+Cx^2+y^2 = 0$
y-Ellipse	ELLY	$Ax+By+Cy^2+x^2 = 0$
Cubic	CUBI(C)	$Ax+By+Cx^2+x^3 = 0$

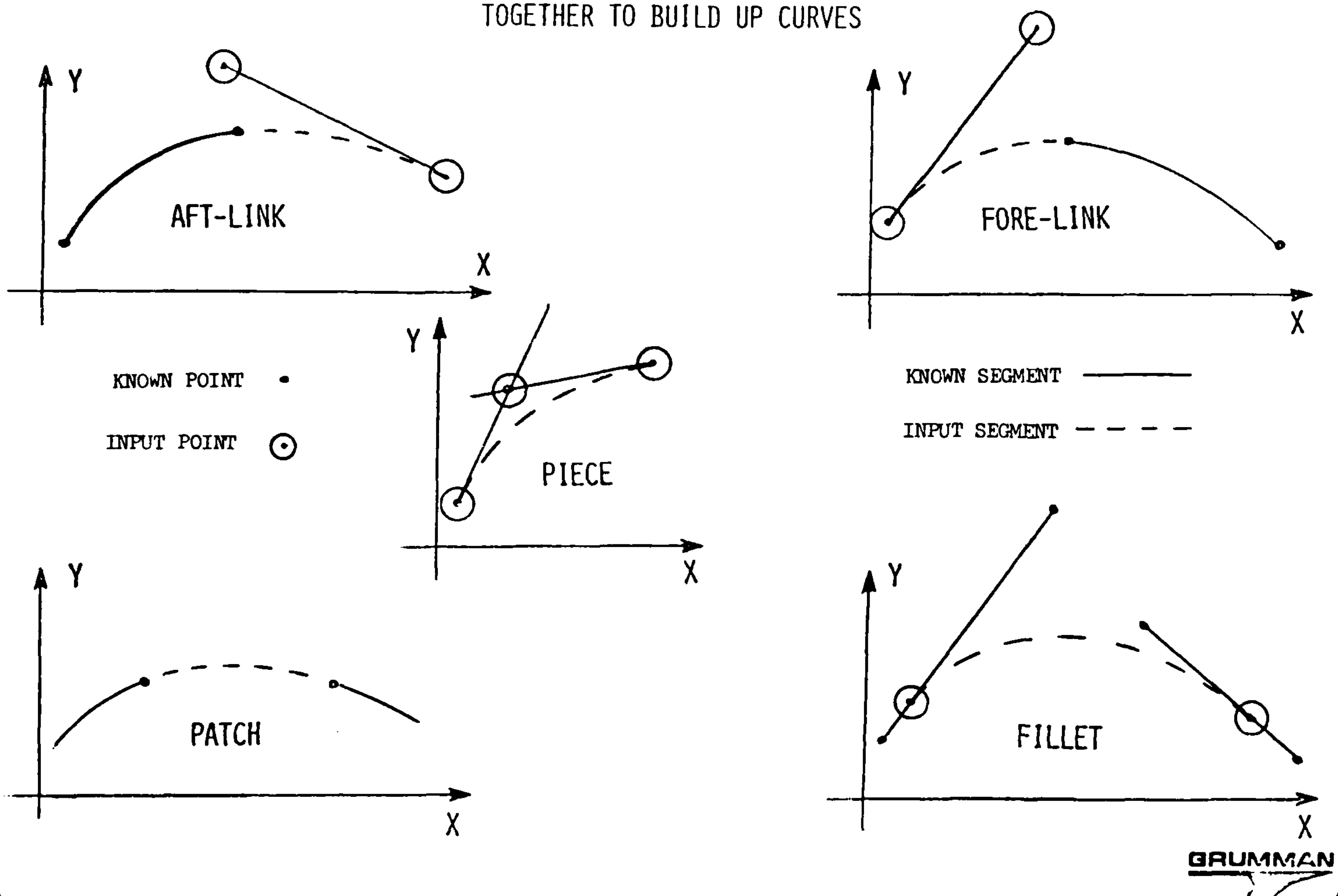


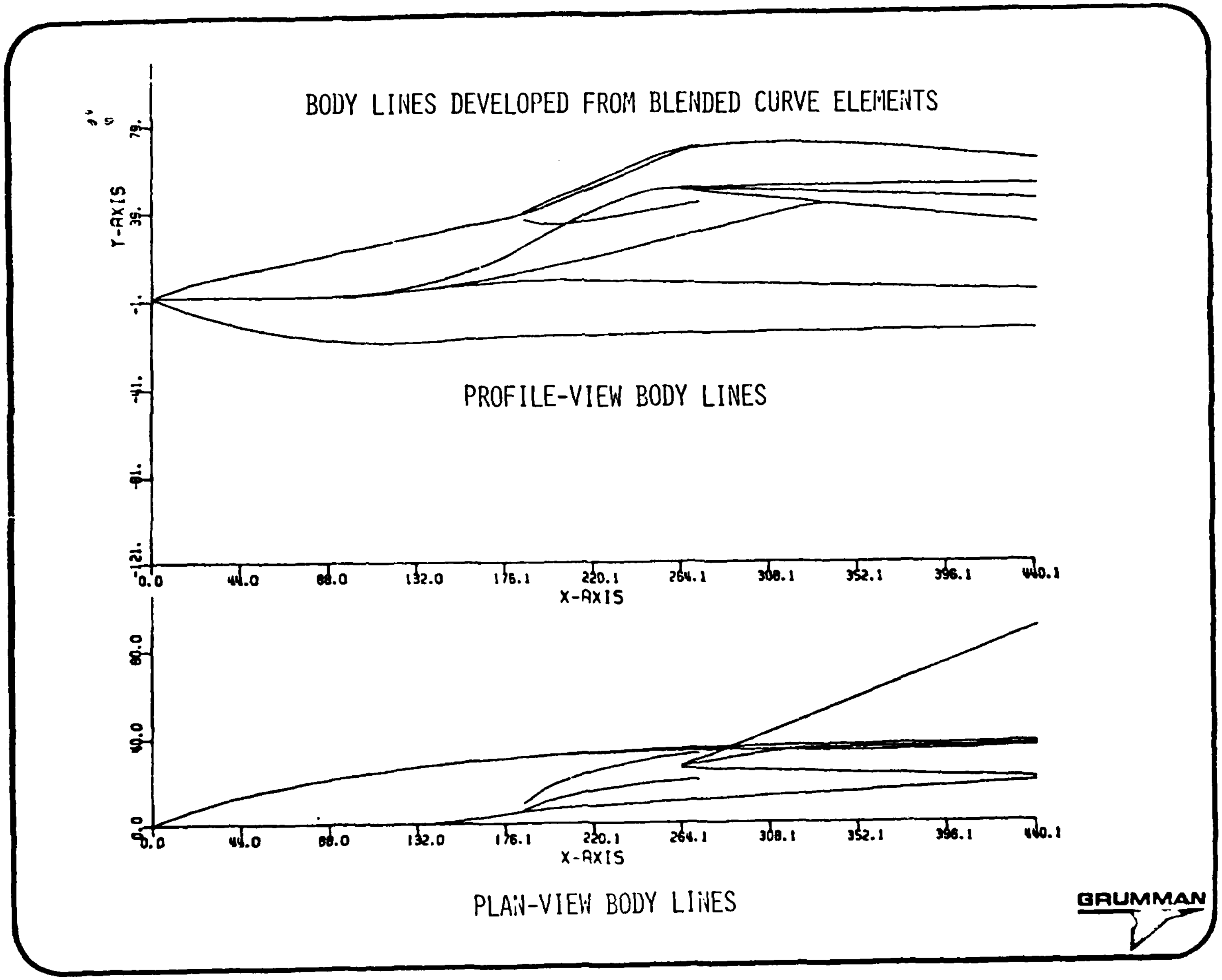
GRUMMAN

BLENDING CONTROL FOR CURVE ELEMENTS

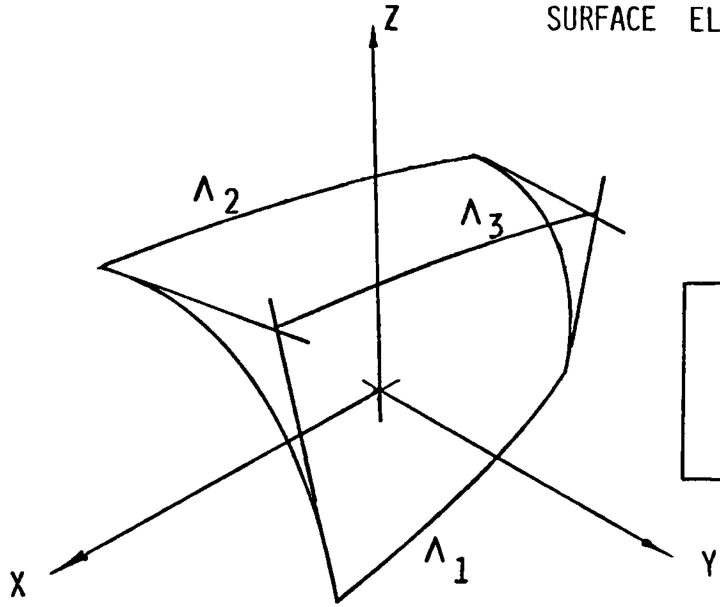
CURVE ELEMENTS ARE BLENDED

TOGETHER TO BUILD UP CURVES




BODY LINES DEVELOPED FROM BLENDED CURVE ELEMENTS
Y-AXIS
79.
39.
-1.
-41.
-81.
-121.
PROFILE-VIEW BODY LINES
0.0
44.0
88.0
132.0
176.1
220.1
264.1
308.1
352.1
396.1
440.1
X-AXIS
80.0
40.0
0.0
0.0
44.0
88.0
132.0
176.1
220.1
264.1
308.1
352.1
396.1
440.1
X-AXIS
PLAN-VIEW BODY LINES
GRUMMAN

SURFACE ELEMENT



Λ_1 - ORIGIN CURVE

Λ_2 - TERMINATION CURVE

Λ_3 - SLOPE CONTROL CURVE

TYPICAL SHAPE ⟶ GROWING ELLIPSE

$$\frac{[Y(X)-Y_o(X)]^2}{A^2(X)} + \frac{[Z(X)-Z_o(X)]^2}{B^2(X)} = 1$$

NOTE THAT QUICK USES BOTH CARTESIAN AND POLAR COORDINATES

POLAR FORM $Q(R, R_o, \theta, \theta_o, A^2, B^2) = 0$

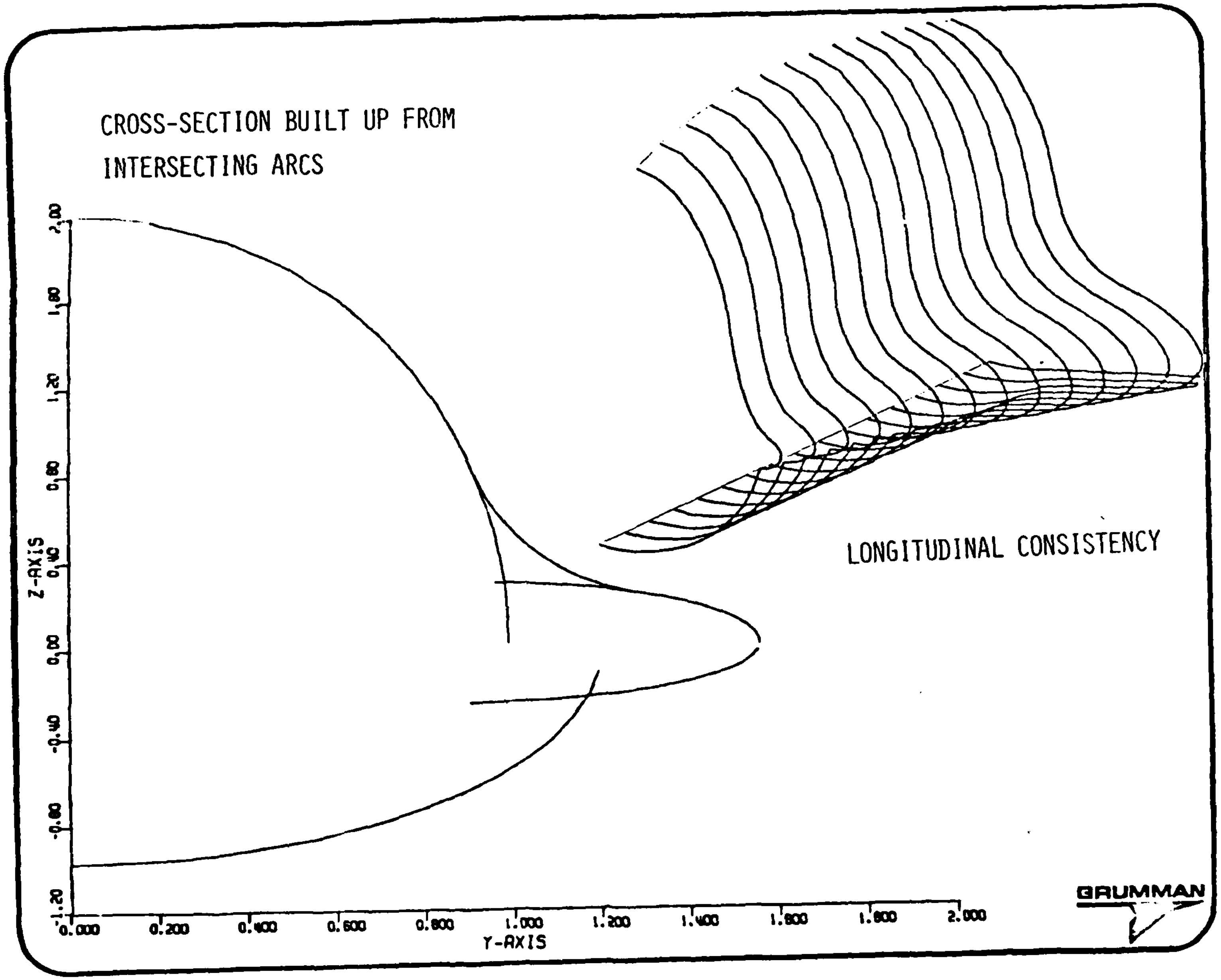
$$B^2 (R \cos\theta - R_o \cos\theta_o)^2 + A^2 (R \sin\theta - R_o \sin\theta_o)^2 - A^2 B^2 = 0$$

WHERE $R_o = R_o(X)$; $\theta_o = \theta_o(X)$; $A^2 = A^2(X)$; $B^2 = B^2(X)$

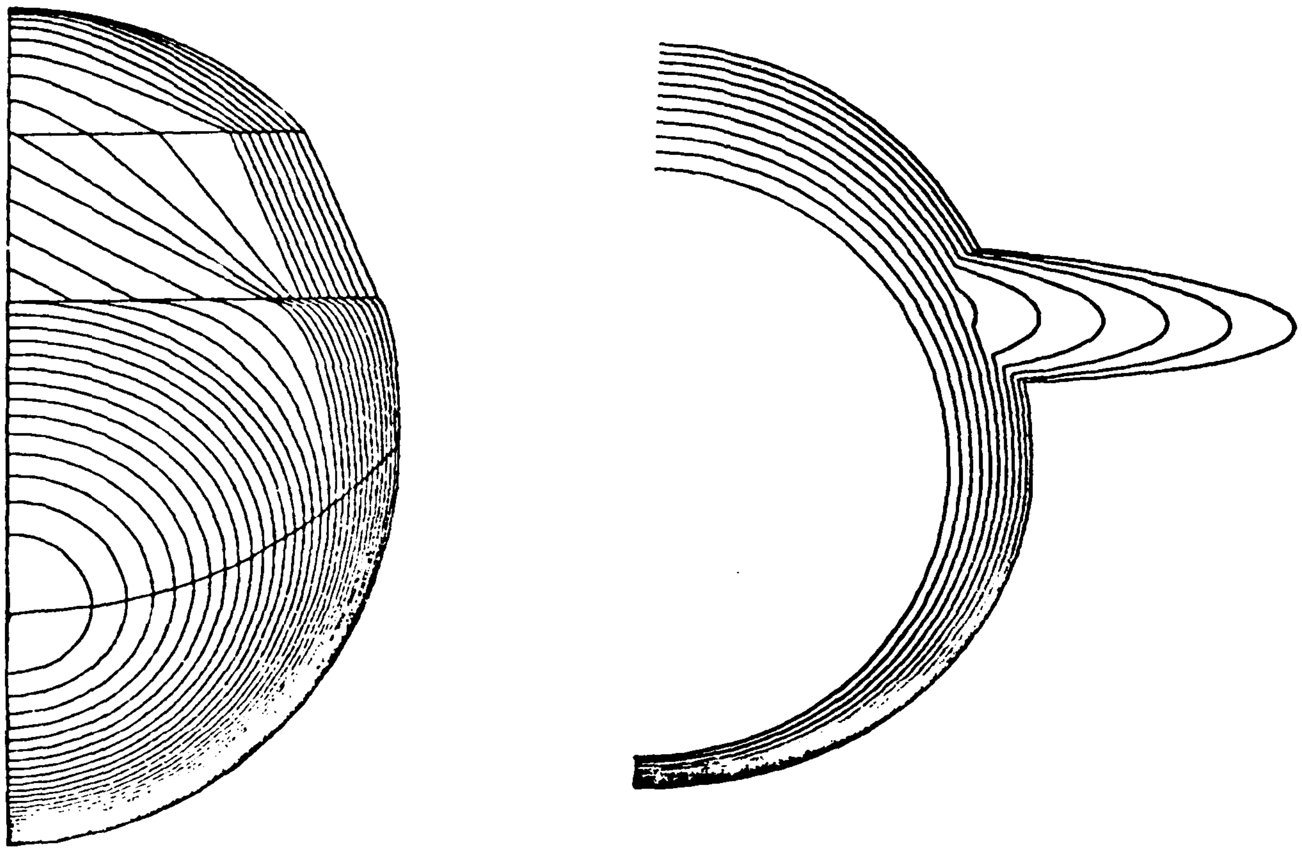
Q IS DIFFERENTIABLE PRODUCING

$$\frac{\partial R}{\partial X}, \frac{\partial R}{\partial \theta}, \frac{\partial^2 R}{\partial X^2}, \frac{\partial^2 R}{\partial X \partial \theta}, \frac{\partial^2 R}{\partial \theta^2}$$

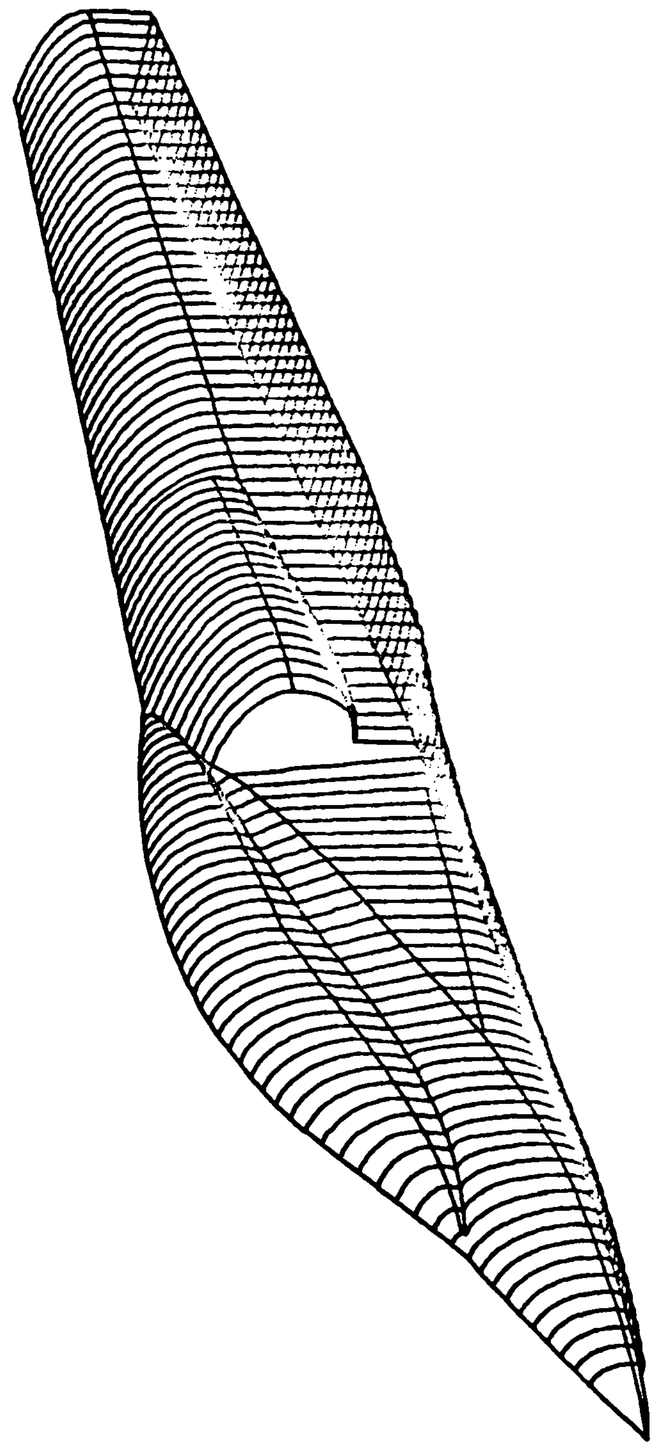
GRUMMAN


CROSS-SECTION BUILT UP FROM
INTERSECTING ARCS
LONGITUDINAL CONSISTENCY
Z-AXIS
Y-AXIS
GRUMMAN
2.00
1.60
1.20
0.80
0.40
0.00
-0.40
-0.80
-1.20
0.000
0.200
0.400
0.600
0.800
1.000
1.200
1.400
1.600
1.800
2.000

DETAILED CROSS-SECTION GEOMETRY

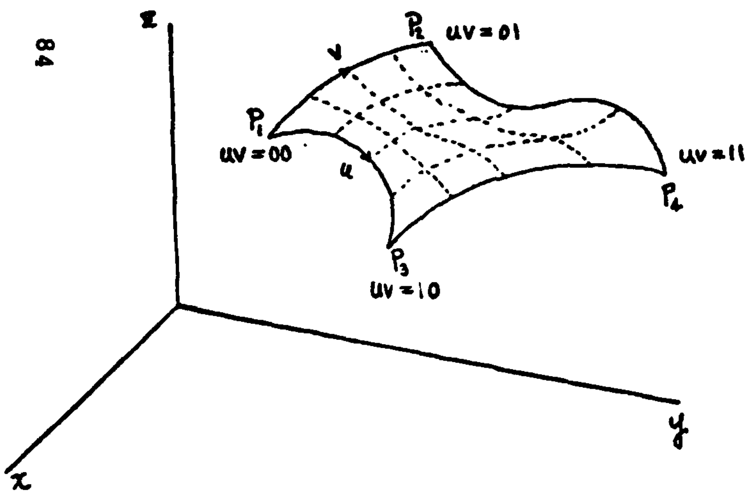


GRUMMAN

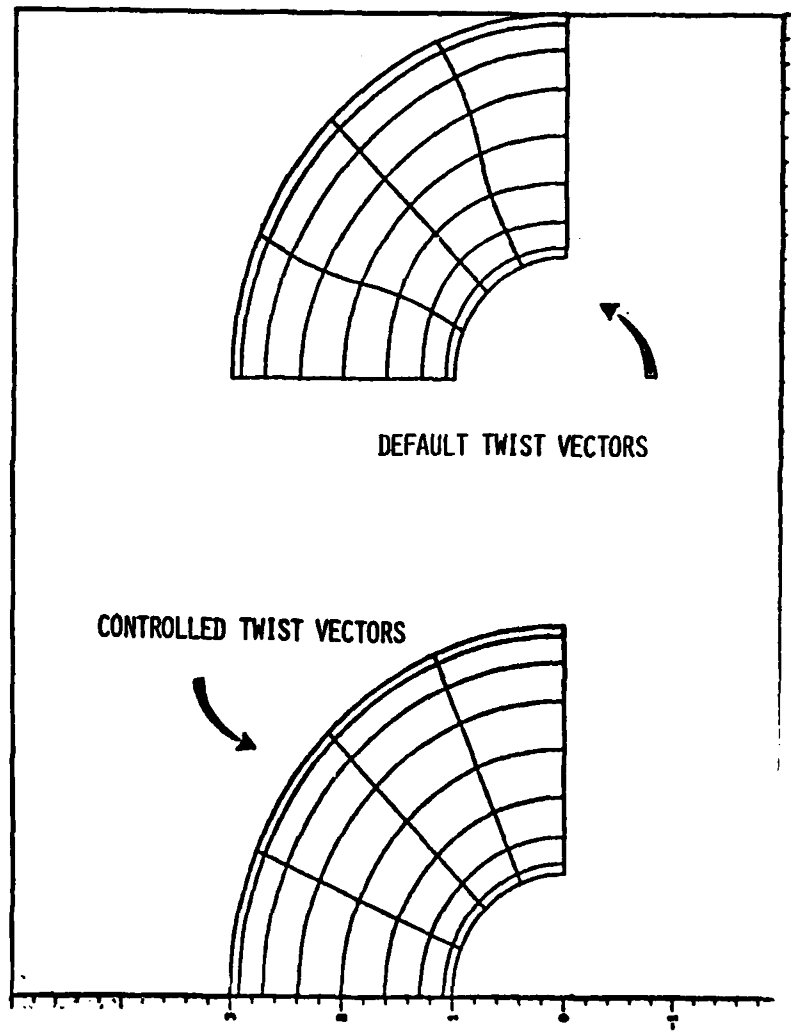


X6 BI-CUBIC PATCH SURFACE

$$P(u,v) = (u^3\ u^2\ u\ 1)\ M^T \begin{bmatrix} P_1 & P_2 & P_{v_1} & P_{v_2} \\ P_3 & P_4 & P_{v_3} & P_{v_4} \\ P_{u_1} & P_{u_2} & P_{uv_1} & P_{uv_2} \\ P_{u_3} & P_{u_4} & P_{uv_3} & P_{uv_4} \end{bmatrix} M \begin{bmatrix} v^3 \\ v^2 \\ v \\ 1 \end{bmatrix}$$



X6 TWIST VECTOR CONTROL



X6 SURFACE DATA STRUCTURE

TOF:

POINTS

	X	Y	Z
1	0.0	0.0	0.0
2	2.000	0.0	0.0
3	0.0	1.000	0.0
4	2.000	1.000	0.0
5	0.0	0.0	0.0
6	3.000	0.0	0.0
7	0.0	0.0	0.0
8	0.0	3.000	0.0
9	0.0	0.0	0.0
10	0.0	0.0	1.000

SLOPES

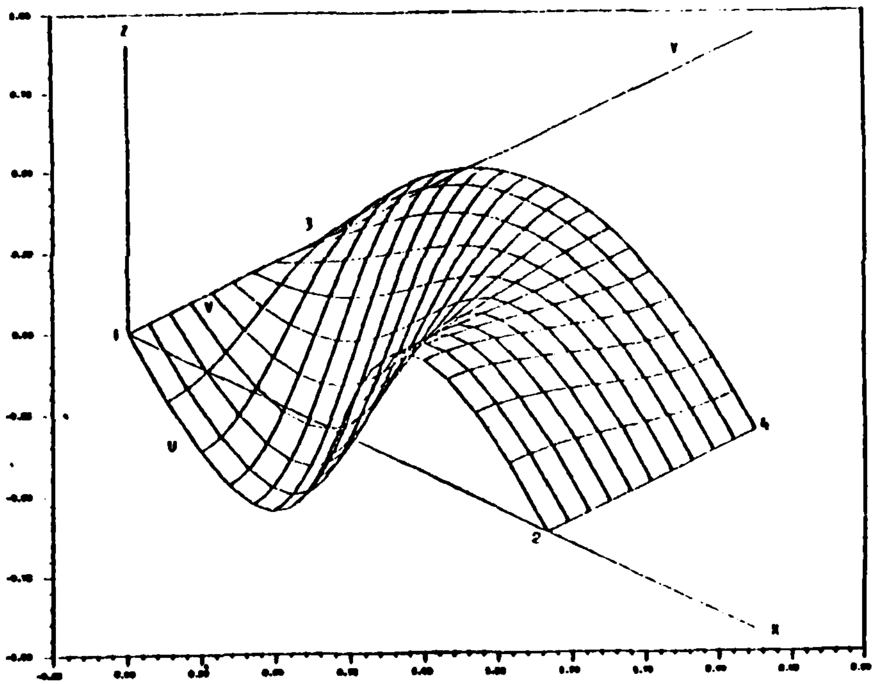
	X	Y	Z
1	4.000	0.0	-4.000
2	4.000	0.0	-4.000
3	2.000	0.0	2.000
4	2.000	0.0	-2.000
5	0.0	1.000	0.0
6	0.0	1.000	0.0
7	0.0	1.000	0.0
8	0.0	1.000	0.0
9	3.030	0.0	0.0
10	3.000	0.0	0.0
11	0.0	3.000	0.0
12	0.0	3.000	0.0
13	0.0	0.0	1.000

LINES

		POINTS		SLOPES		COLOR
1	0	1	2	1	1	1
2	0	3	4	3	4	1
3	0	1	3	5	5	1
4	0	2	4	7	7	1
5	0	5	6	9	9	1
6	0	7	8	11	11	1
7	0	9	10	13	13	1

SURFACES

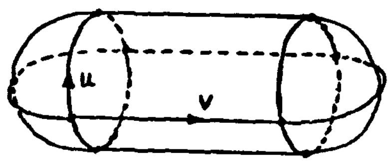
		LINES				TWIST TERMS				SURFACE COLOR		GRID LINES	
1	0	1	2	3	4	0	0	0	0	1	1	9	19



X6 DERIVATIVE VECTOR CODES

0 — CONTINUOUS VECTOR
1 — LINEAR VECTOR
2 — NEIGHBOR VECTOR
3 — NO CONNECTION
4 — EXTERNAL VECTOR
5 — FREE END VECTOR

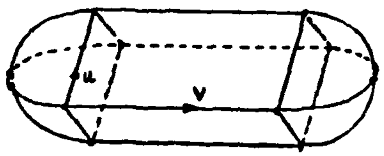
Example 1:



4 X 4 NODES

u	00	00	00	00
v	42	11	24	33

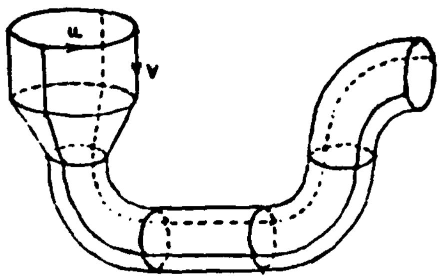
Example 2:



4 X 4 NODES

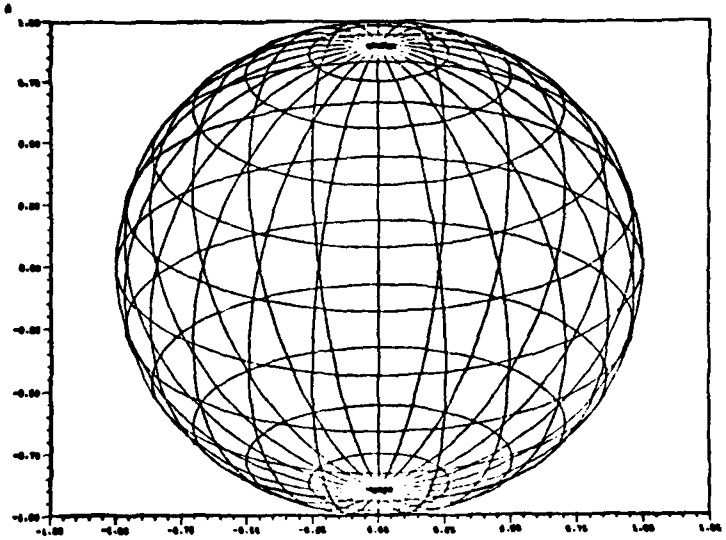
u	11	11	11	11
v	42	11	24	33

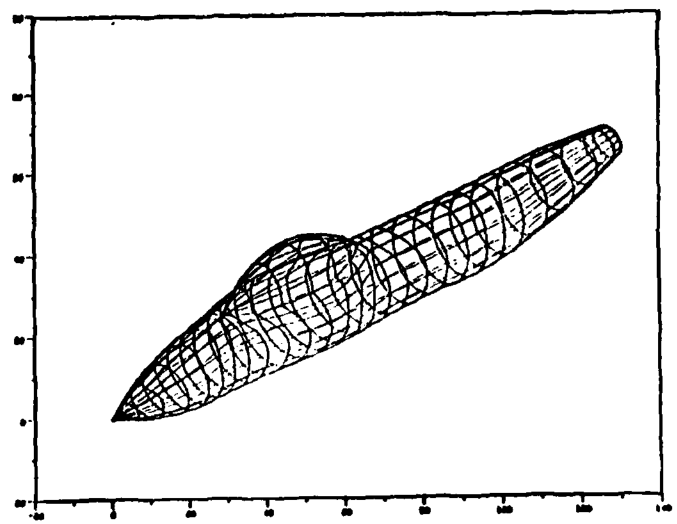
Example 3:

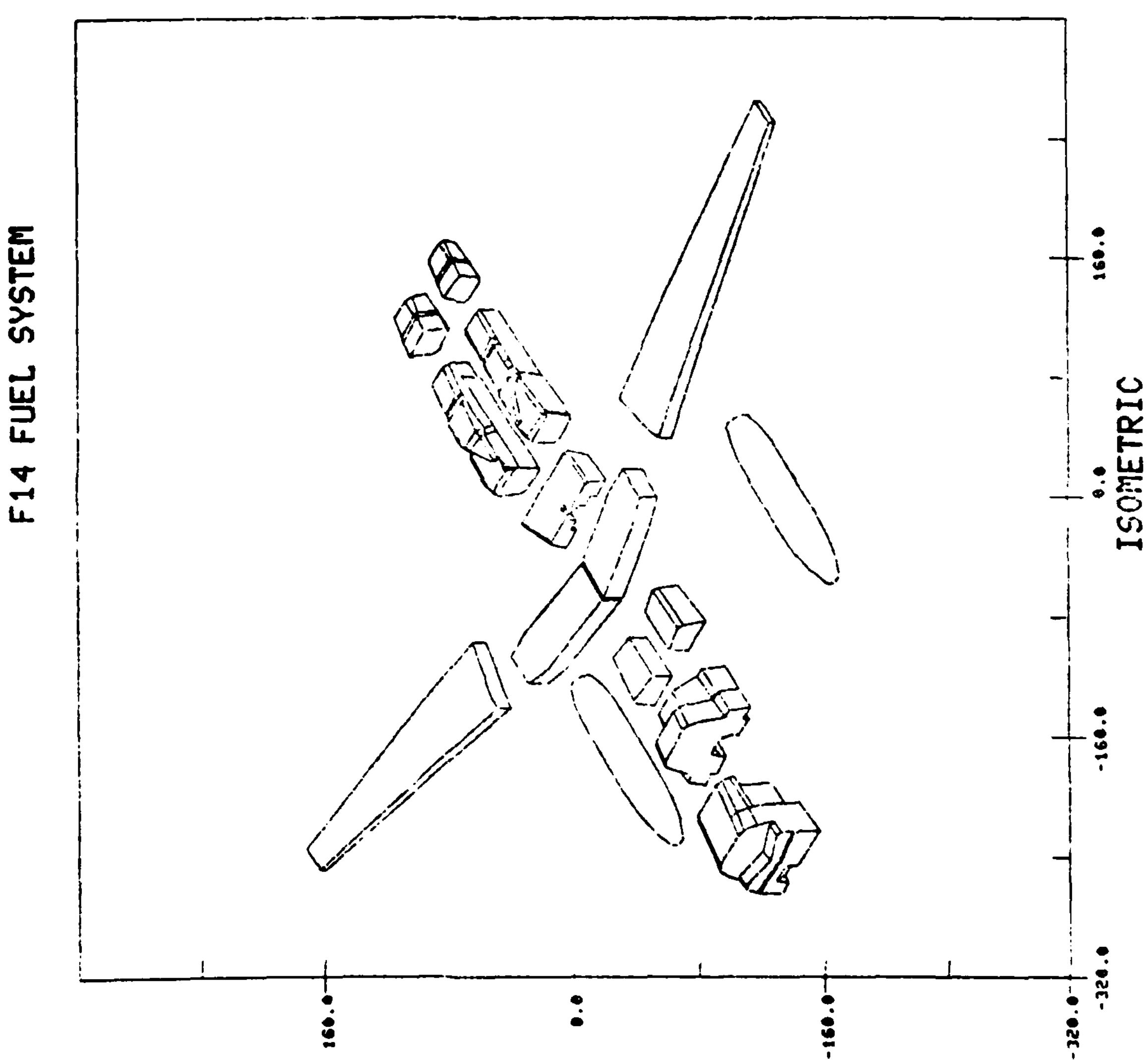


4 X 7 NODES

u 00 00 00 00
v 11 11 42 11 24
24 33

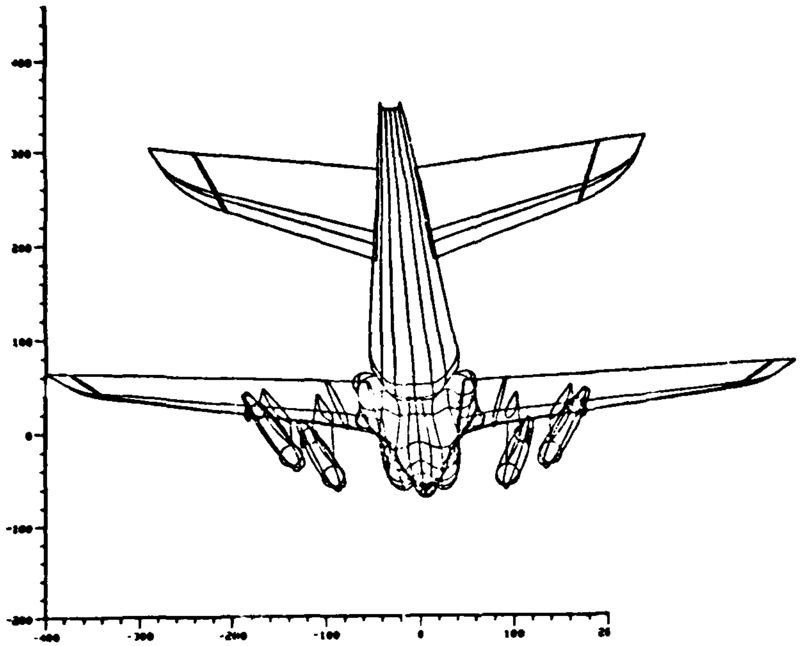


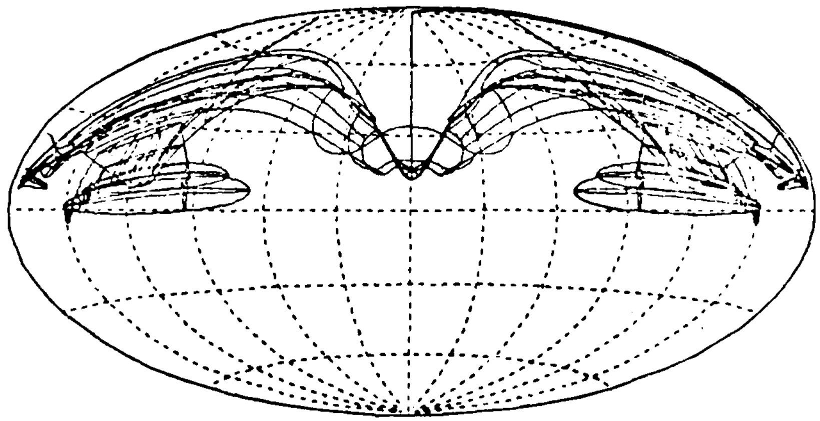



F14 FUEL SYSTEM
ISOMETRIC
160.0
0.0
-160.0
-320.0

AITOFF VISION PROJECTION PER MIL-STD 850 B

EA6B ANTENNA STUDY



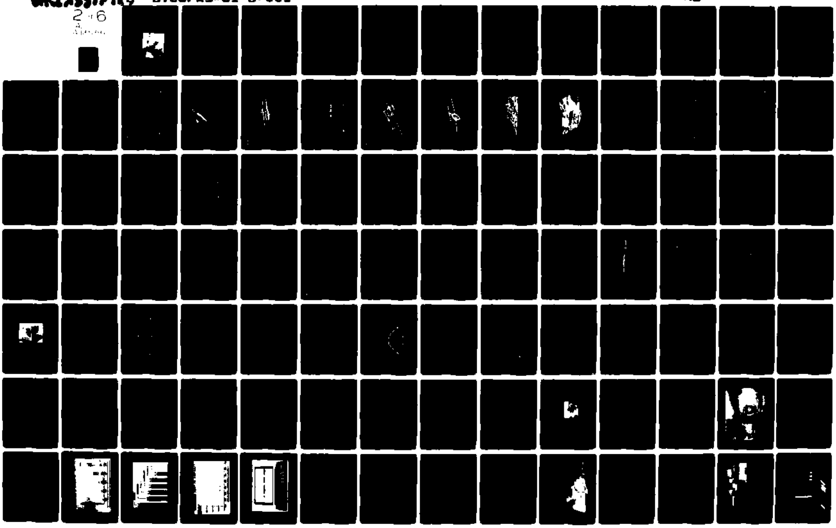


VISION CL DATA
STA 205.500
BL 0.0
WL 25.300
AZ 0.0
EL 6.000

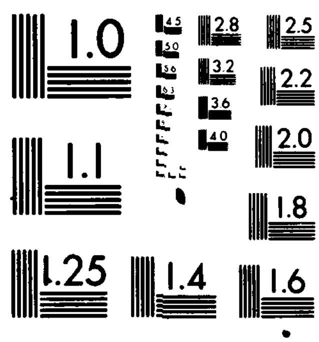
AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981

UNCLASSIFIED JTCG/AS-81-D-001 NL

2 of 6



UNCL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FAIRCHILD REPUBLIC COMPANY'S PRIME ACTIVITY:
AN INTEGRATED APPROACH TO CAD AND CAM

Rocco Ruggiero
Manager Analytical Services
Fairchild Republic Company
Farmingdale, New York

ROCCO RUGGIERO
FAIRCHILD REPUBLIC COMPANY

FAIRCHILD REPUBLIC COMPANY'S PRIME ACTIVITY:
AN INTEGRATED APPROACH TO CAD AND CAM

Rocco Ruggiero
Manager Analytical Services
Fairchild Republic Company
Farmingdale, New York

The Fairchild Republic Company, since the early part of 1979, has undertaken a concentrated effort to automate its engineering design process and to completely integrate it with manufacturing operations. This effort is embodied in its PRIME program, PR for Integrating Manufacturing and Engineering in an interactive mode. The PRIME program, whose ultimate objective is a complete integrated factor, consists of an ICAD project, a CAD/CAM operation and a Data Base Management (DBM) Section. ICAD seeks to convert technical analysis application software from batch mode to interactive and to add graphic capability. This conversion is paced to the aircraft design process with the first accomplishments being in the aircraft sizing and trade study process. The modules comprising this process are described. The CAD/CAM operations include two Computervision "turnkey" systems with 10 work stations. Also, a study of a CADAM alternative is underway. The DBM Section is developing hardware and software for managing a comprehensive technical data base which will have at its core a geometry data base. Details of all of this are given as well as examples of various graphics developments: machining drawings, tool path control, FEM model development, vehicle design depiction. The dynamic graphics developments in FRC's TASEM/MAPS program, which advances the state-of-the-art in computer graphic depiction of combat operations, are also illustrated.

FAIRCHILD REPUBLIC COMPANY'S

PRIME ACTIVITY:

AN INTEGRATED APPROACH

TO CAD AND CAM

FAIRCHILD
REPUBLIC COMPANY
FARMINGDALE, L.I., NEW YORK 11735

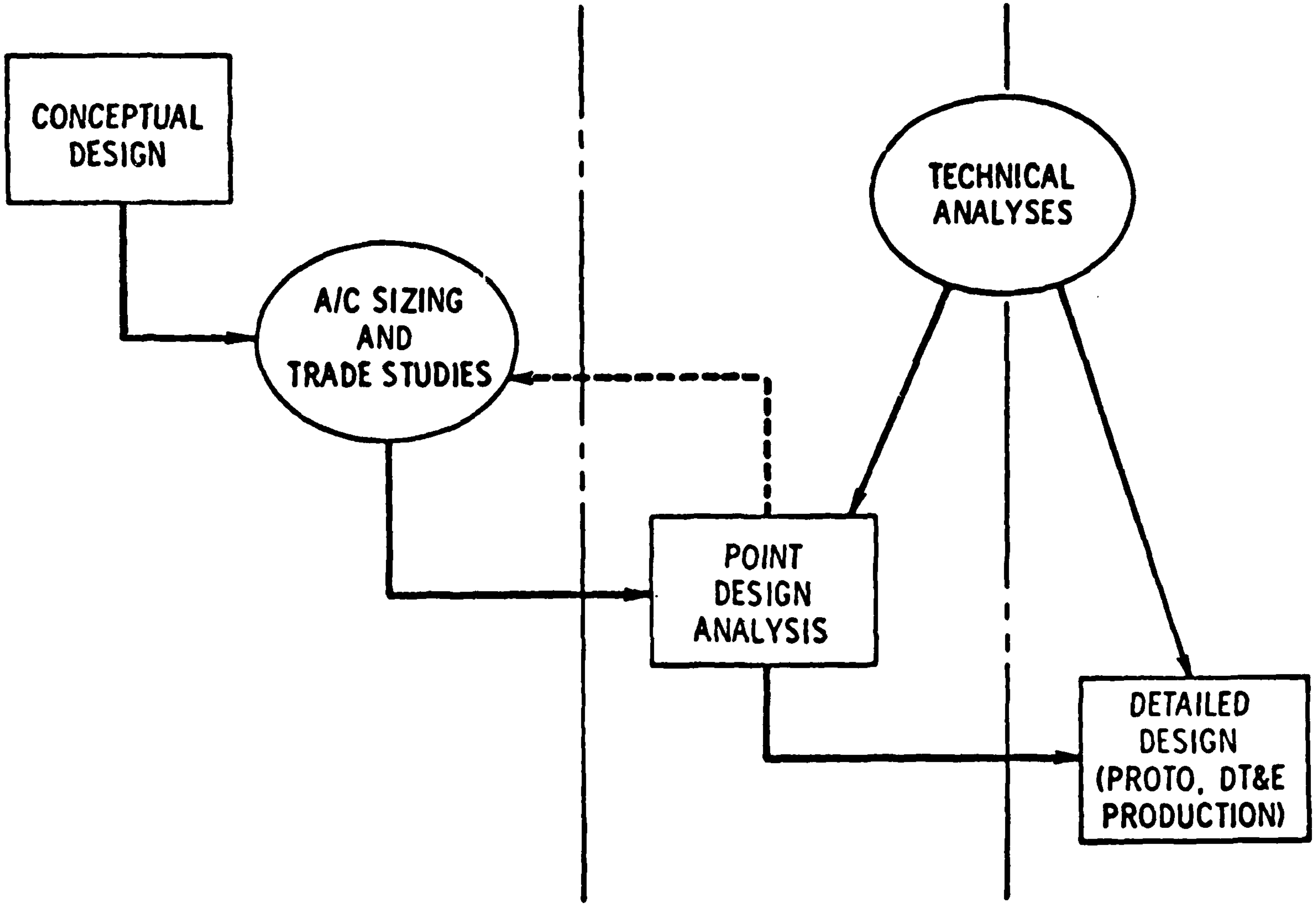
PROGRAM TO INTEGRATE MANUFACTURING AND ENGINEERING (PRIME)

- THE INITIAL STEP AT FRC TOWARD OVERALL FACILITY AUTOMATION
- ESTABLISHED IN 1979 IN THE ENGINEERING DEPARTMENT
- GOAL: OPTIMIZE THE FRC DESIGN-TO-MANUFACTURING PROCESS THROUGH EXPLOITATION OF STATE-OF-THE-ART COMPUTER-BASED CAPABILITIES
- BENEFITS:
  - MAKE CURRENT EMPLOYEES MORE PRODUCTIVE AND MOTIVATED
  - REDUCES REQUIREMENTS TO HIRE AND TRAIN NEW EMPLOYEES
  - ATTRACTS A BETTER CLASS OF YOUNG PROFESSIONALS TO FRC
  - EXPEDITES THE TRAINING OF ALL PERSONNEL

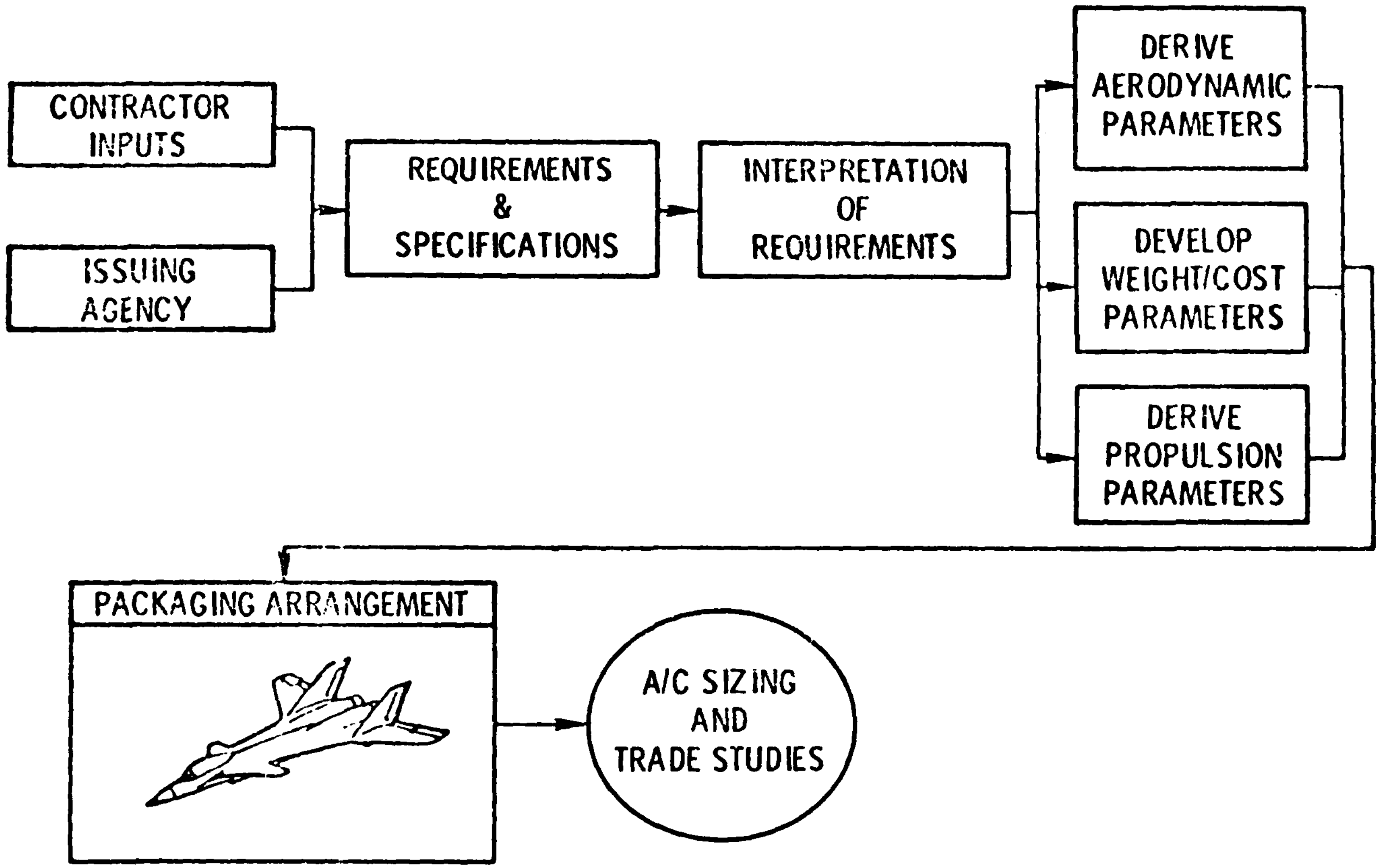
PRIME IS COMPRISED OF:

- INTERACTIVE COMPUTER-AIDED DESIGN (ICAD) PROJECT
- COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM) PROJECT
- DATA BASE MANAGEMENT SECTION

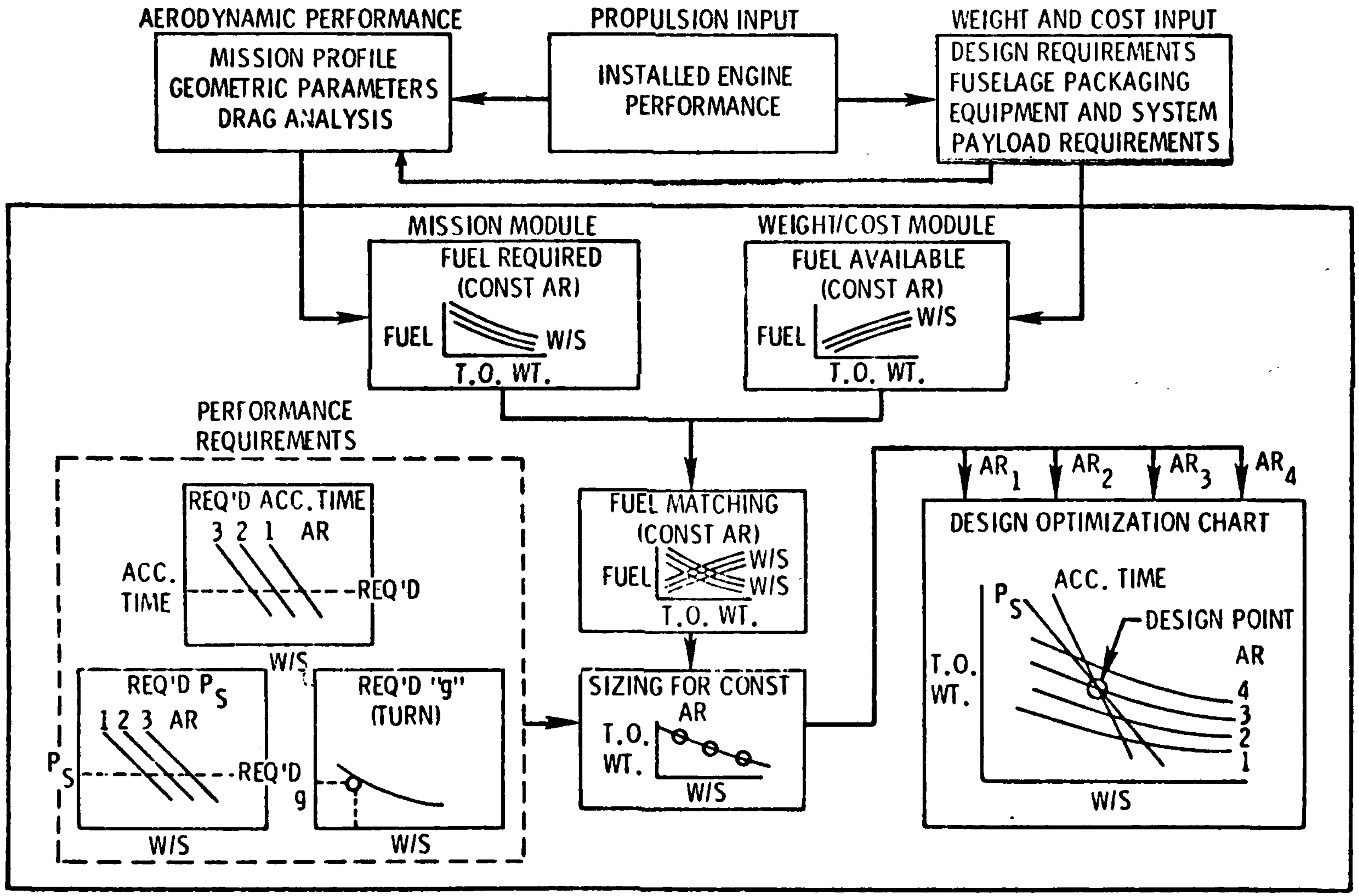
OVER-ALL DESIGN PROCESS



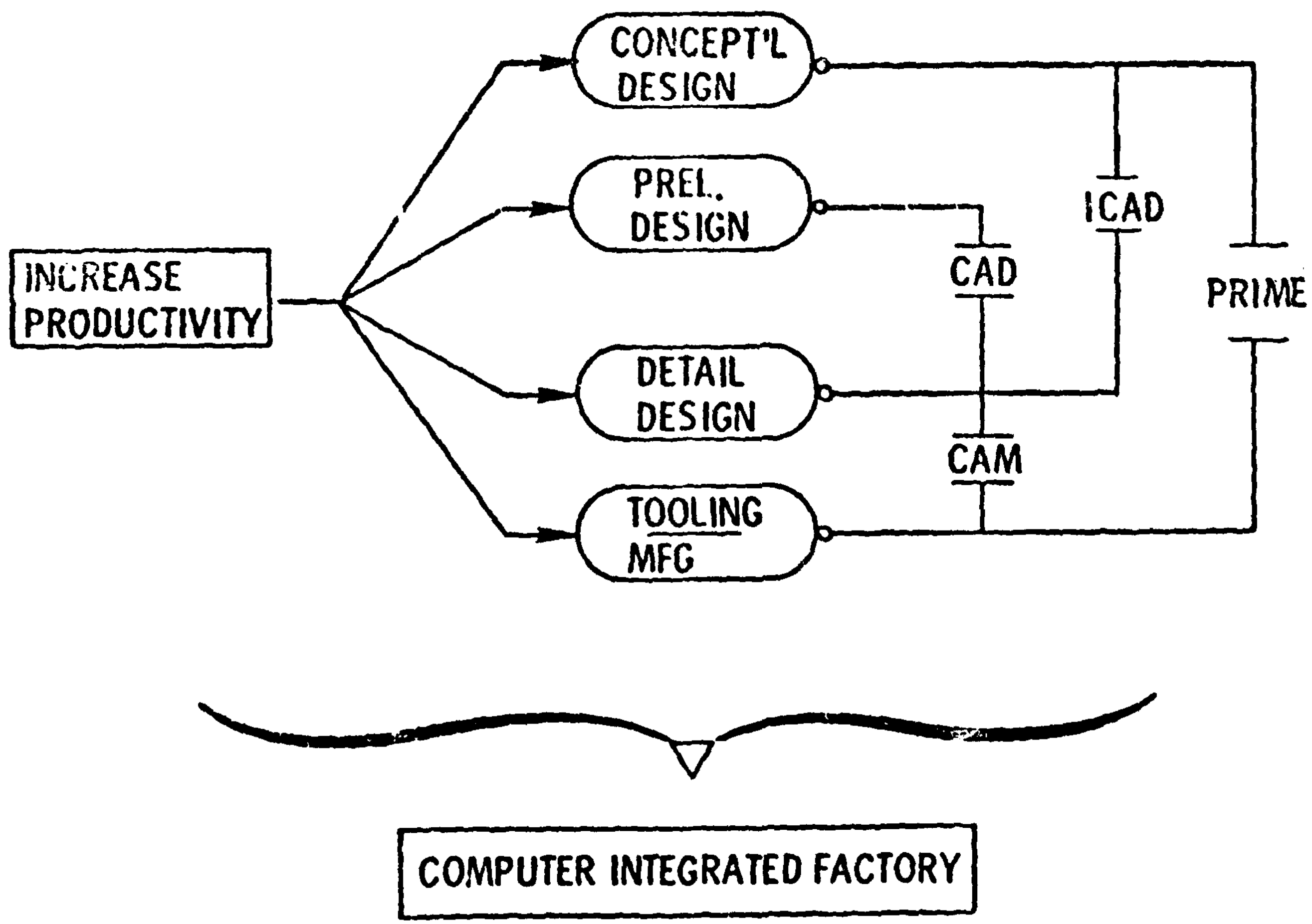
CONCEPTUAL DESIGN PROCESS



AIRCRAFT SIZING/TRADE–STUDY PROCESS



CAD/CAM IS PART OF PRIME



PROJECT ROLES - ELEMENTS OF PRIME

ICAD: IMPROVE CONCEPTUAL, PRELIMINARY AND DETAILED DESIGN FUNCTIONS THROUGH CONVERSION OF TECHNICAL ENGINEERING TO INTERACTIVE, INTEGRATED ENVIRONMENT

CAD/CAM: ESTABLISH INTERACTIVE COMPUTER GRAPHICS SYSTEMS TO SUPPORT ENGINEERING/MANUFACTURING IN PRELIMINARY, DETAILED DESIGN, NUMERICAL CONTROL & TOOLING FUNCTIONS

DATA BASE MGT. SECTION:

INSTALLATION AND MAINTENANCE OF A DATA BASE SYSTEM TO SUPPORT ICAD AND CAD/CAM ACTIVITIES

THE CURRENT ICAD ENVIRONMENT

GRAPHICS CRT TERMINALS & SUPPORTING EQUIPMENT (TEXTRONIX)
- 3 "DUMB" (4014) TERMINALS
- 2 INTELLIGENT (4051/2) TERMINALS
- GRAPHICS (4081) SYSTEM W/DISC DRIVE
- 2 HARD COPY UNITS
- 2 PLOTTERS
- 1 DIGITIZER

ALPHANUMERIC TERMINALS
- 5 LEAR-SIEGLER CRT TERMINALS
- 2 TTY TERMINALS
- ITT-COURIER INFO DISPLAY SYSTEM (W/9 TERMINALS + PRINTER)

COMPUTER SUPPORT PROVIDED BY CORPORATE HQ IBM 4341
VIA TELEPHONE COMMUNICATIONS LINES
OPERATING SYSTEM: OS/MVT (W/TSO) CONVERTING TO VM/CMS (AND VS1)

ICAD PROJECT - ACCOMPLISHMENTS

COMPONENT MODULES OF AIRCRAFT SIZING PROCESS MADE INTERACTIVE
- AEROCHARACTERISTICS PROGRAM
- PROPULSION MODULE(S)
- WEIGHTS/COST PROGRAM
- MISSION PROGRAM

CONVERSION OF CRITICAL ANALYSIS PROGRAMS TO INTERACTIVE MODE
- VORTEX LATTICE SUBSONIC LOADS PROGRAM
- SHEARS, MOMENTS, TORQUES COMPUTATIONS
- FUSELAGE SHEARS AND BENDING MOMENTS

DEVELOPMENT OF AIRCRAFT MODELING CAPABILITY
- ACQUISITION, CONVERSION TO IBM, OF NASA GEMPAK PROGRAM
- ENHANCEMENT OF GEMPAK TO ALLOW PLOTTING AND MULTI-BODIES

DEVELOPMENT OF ICAD EXECUTIVE ROUTINE FOR CMS ENVIRONMENT

FORMATION OF ICAD ADVISORY COMMITTEE
- PROMOTES USER INVOLVEMENT IN
  - ICAD TASK PLANNING
  - TRAINING
  - SELECTION OF ICAD TASK MONITORS
- MEETINGS HELD WEEKLY

ICAD PROJECT - CURRENT ACTIVITIES

MOVE OF INTERACTIVE PROCESSING TO CMS ENVIRONMENT

- TRAINING OF PROGRAMMERS NEARING COMPLETION
- CONVERSION OF PROGRAMS UNDERWAY
- TRAINING OF USERS INITIATED

ENHANCE/IMPROVE SIZING PROCESS

AIRCRAFT MODELING CAPABILITY DEVELOPMENT

- ENHANCEMENT OF GEMPAK (MULTI-BODY PLOTTING; MASS PROPERTIES)
- DEFINITION OF REQTS FOR COMMON GEOMETRY DATA BASE

TRAINING/CONSULTATION FOR TECHNICAL ENGINEERING ANALYSTS IN:

- UTILIZATION OF LOCAL AND REMOTE INTERACTIVE CAPABILITIES
- OPERATION/DEVELOPMENT OF LOCAL AND SPECIALIZED PROGRAMS

IMPLEMENTATION OF INTERACTIVE FEM CAPABILITY

DEVELOP/IMPROVE AUTOMATED ELEMENTS OF CONCEPTUAL/PRELIMINARY DESIGN PROCESS

DEVELOPMENT OF NASTRAN POST-PROCESSORS

INSTALLATION OF IMPROVED VERSION OF VORTEX-LATTICE PROGRAM

ICAD PROJECT - PLANNED ACTIVITIES

IN CONJUNCTION WITH ICAD ADVISORY COMMITTEE, ESTABLISH TASKS TO:

- CONVERT SELECTED ANALYSES PROGRAMS TO INTERACTIVE MODE
- ACQUIRE/DEVELOP SOFTWARE TO FILL GAPS IN AUTOMATED DESIGN PROCESS
- TRAIN/FAMILIARIZE USERS IN OPERATION OF ICAD-DEVELOPED SOFTWARE
- DOCUMENT ICAD-DEVELOPED SOFTWARE

CONTINUE DEVELOPMENT OF GEOMETRY MODELING CAPABILITY

- ESTABLISH GEOMETRY DATA BASE
- INSTALL AS INTEGRAL PART OF A/C SIZING PROCESS
- INTERFACE WITH OTHER TECHNICAL ANALYSES PROGRAMS

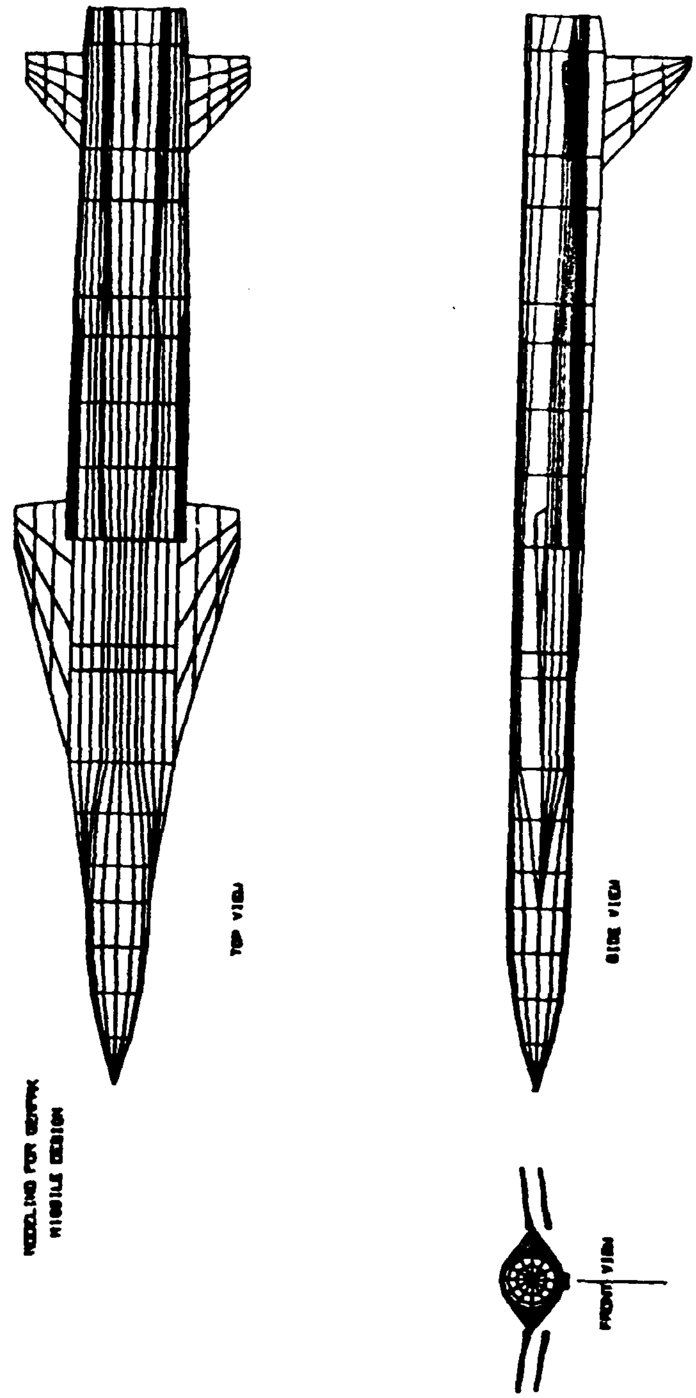
INSTALLATION OF ICAD-DEVELOPED SOFTWARE INTO COMPUTER PROGRAM CONTROL SYSTEM USING ICAD EXECUTIVE ROUTINE

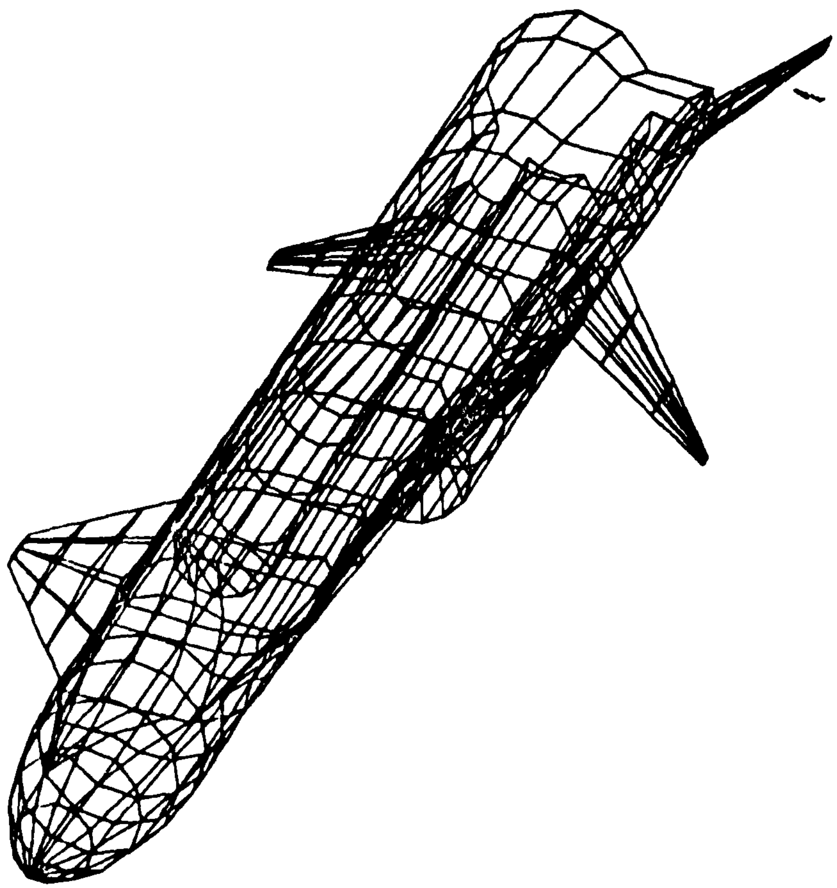
AUGMENT ELEMENTS OF DESIGN PROCESS WITH ADDITIONAL INTERACTIVE GRAPHICS DISPLAYS

ACQUIRE ADDITIONAL INTERACTIVE TERMINALS & SUPPORTING PERIPHERALS (1981-85)

- 9 INTELLIGENT GRAPHICS TERMINALS WITH FLOPPY DISC DRIVES
- 3 HARD-COPY UNITS, PLOTTER, DIGITIZER
- IBM 3270 INFO DISPLAY SYSTEM W/20 CRT TERMINALS + PRINTER

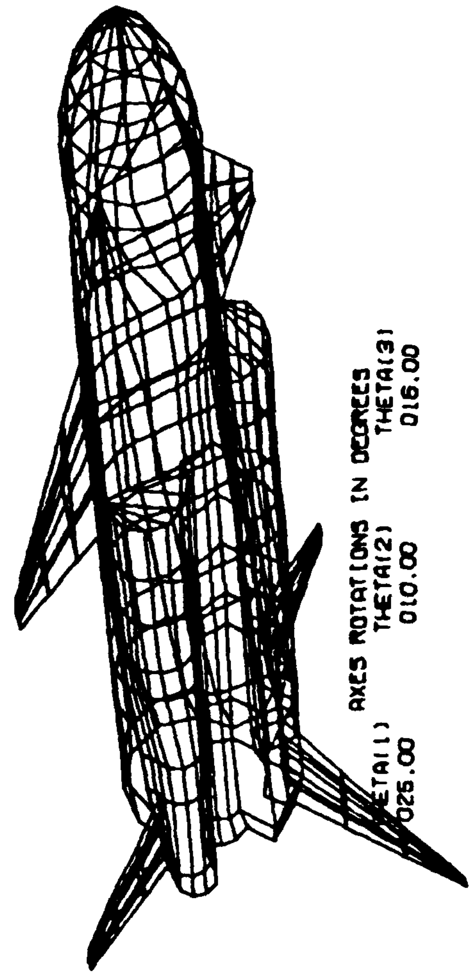
CONVERSION OF PROCESSING TO LOCAL COMPUTER FACILITY


TOP VIEW
SIDE VIEW
FRONT VIEW
MODELING FOR
MISSILE DESIGN

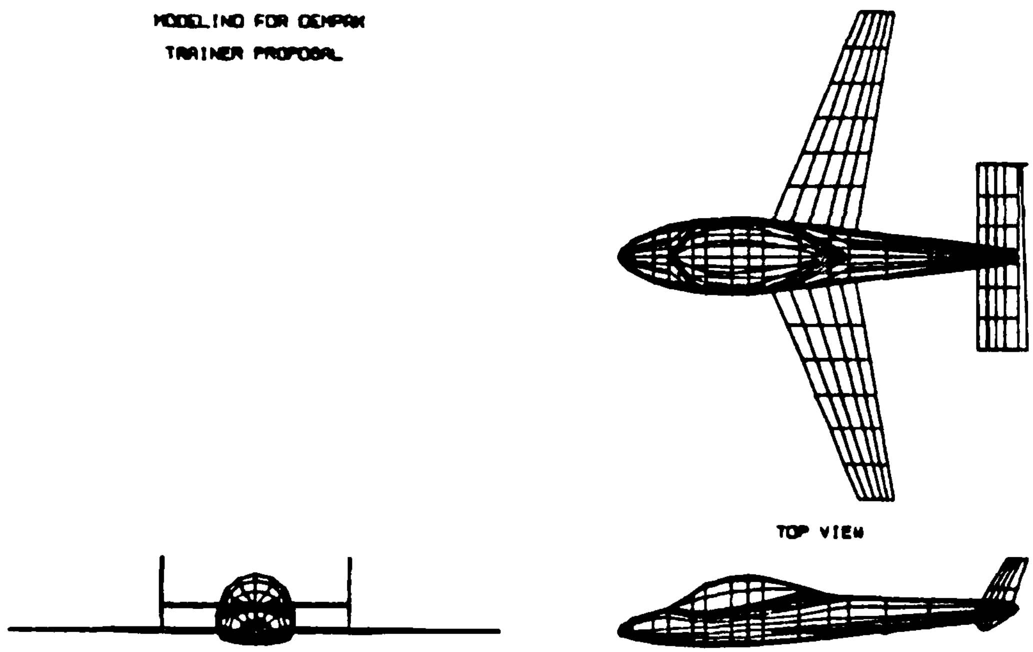


AXES ROTATIONS IN DEGREES

THETA(1)	THETA(2)	THETA(3)
-025.00	-010.00	-016.00


AXES ROTATIONS IN DEGREES
THETA(1) THETA(2) THETA(3)
026.00 010.00 016.00

MODELING FOR DEMPAK
TRAINER PROPOSAL

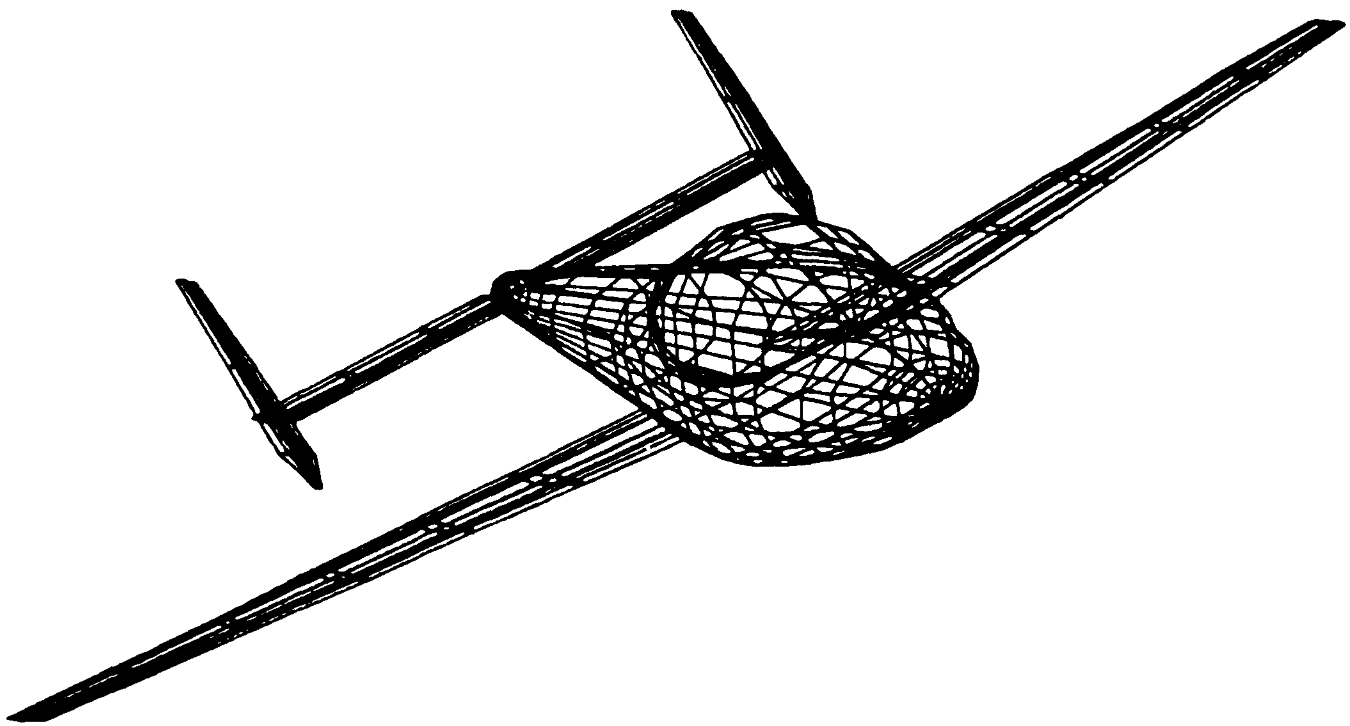


TOP VIEW

FRONT VIEW

SIDE VIEW

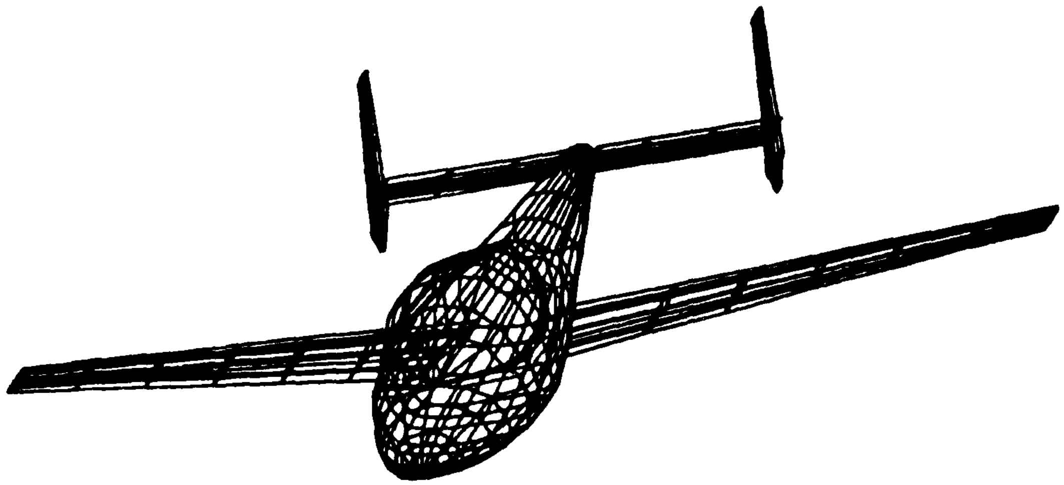
MODELING FOR DEMPAK
TRAINER PROPOSAL



AXES ROTATIONS IN DEGREES

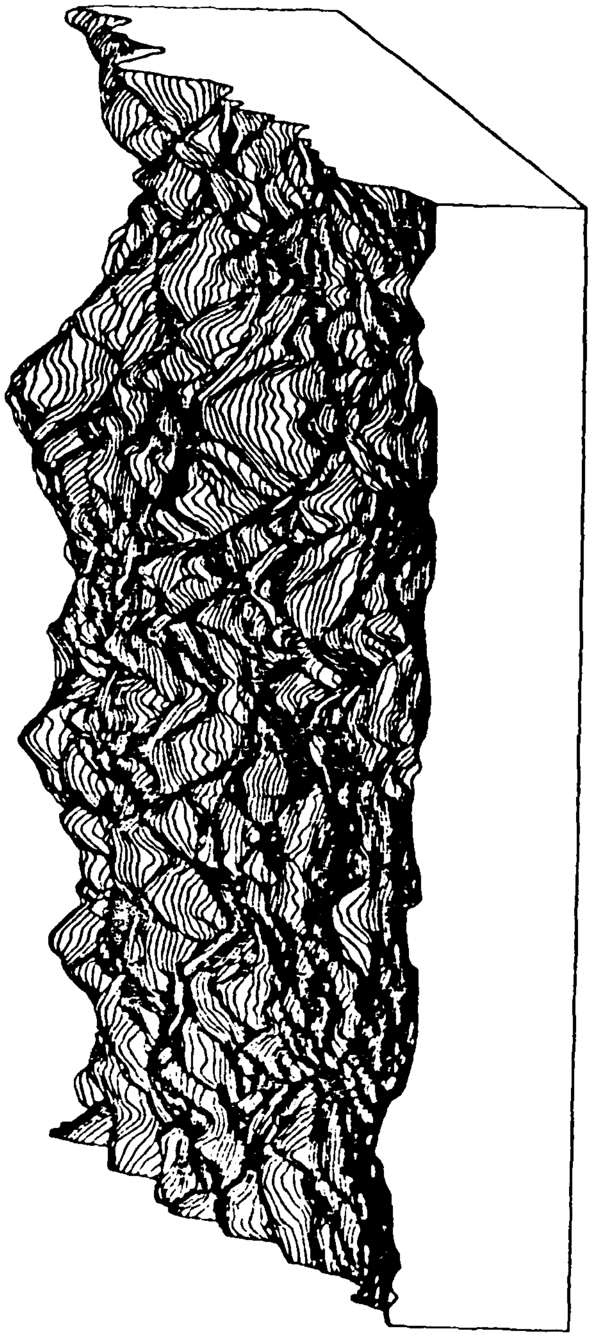
THETA(1)	THETA(2)	THETA(3)
-025.00	-010.00	016.00

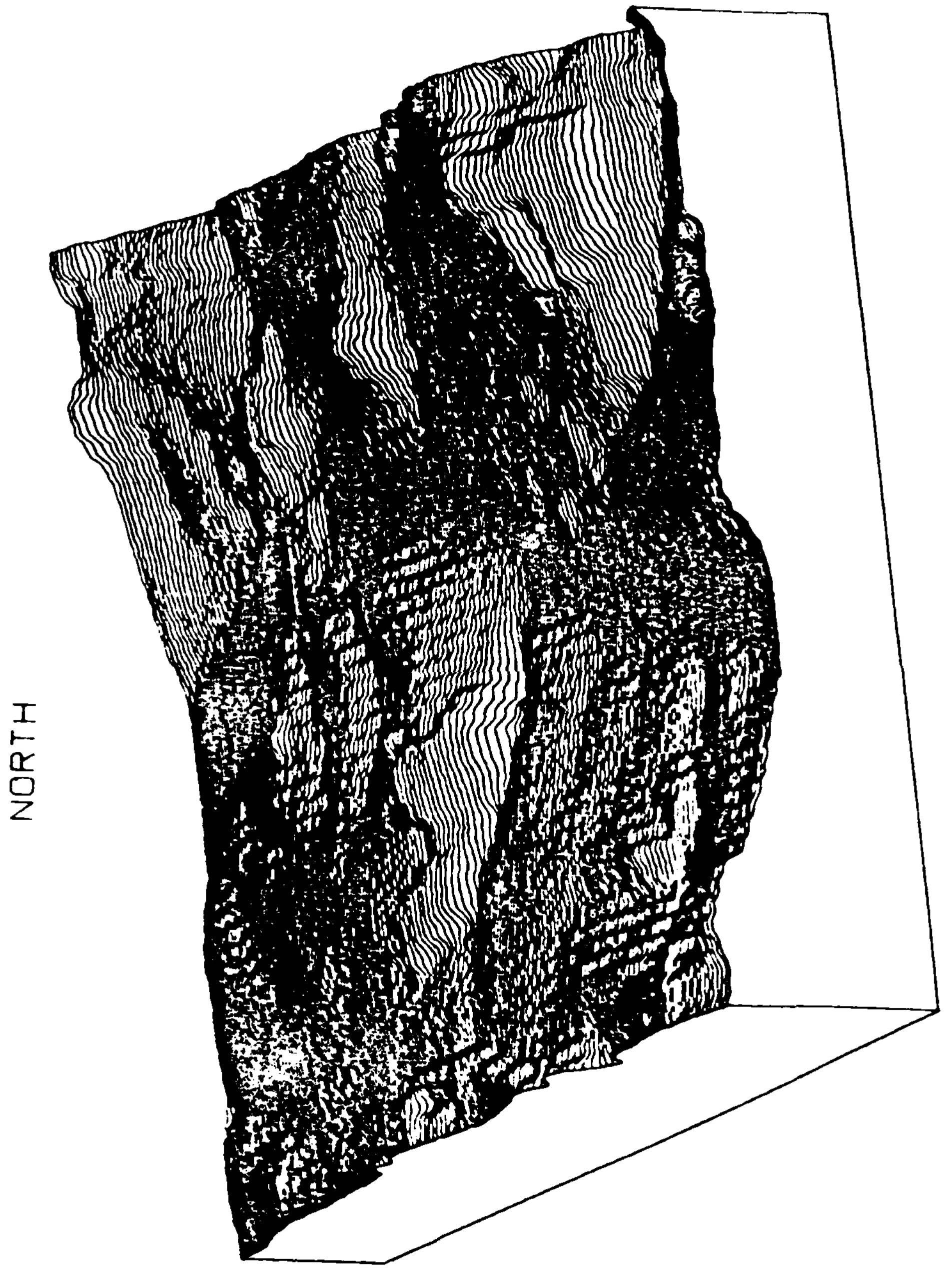
MODELING FOR GEMPAK
TRAINER PROPOSAL

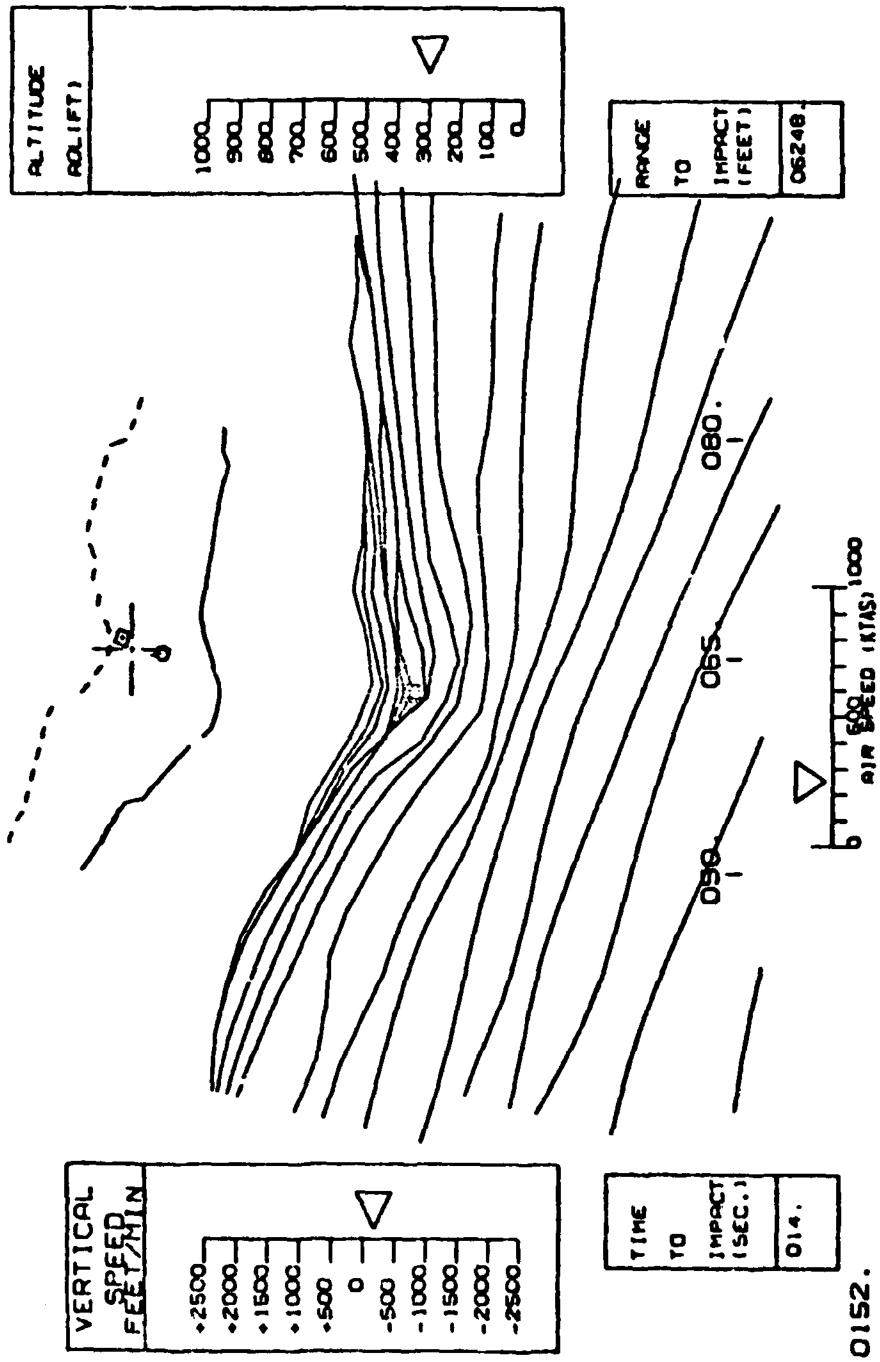


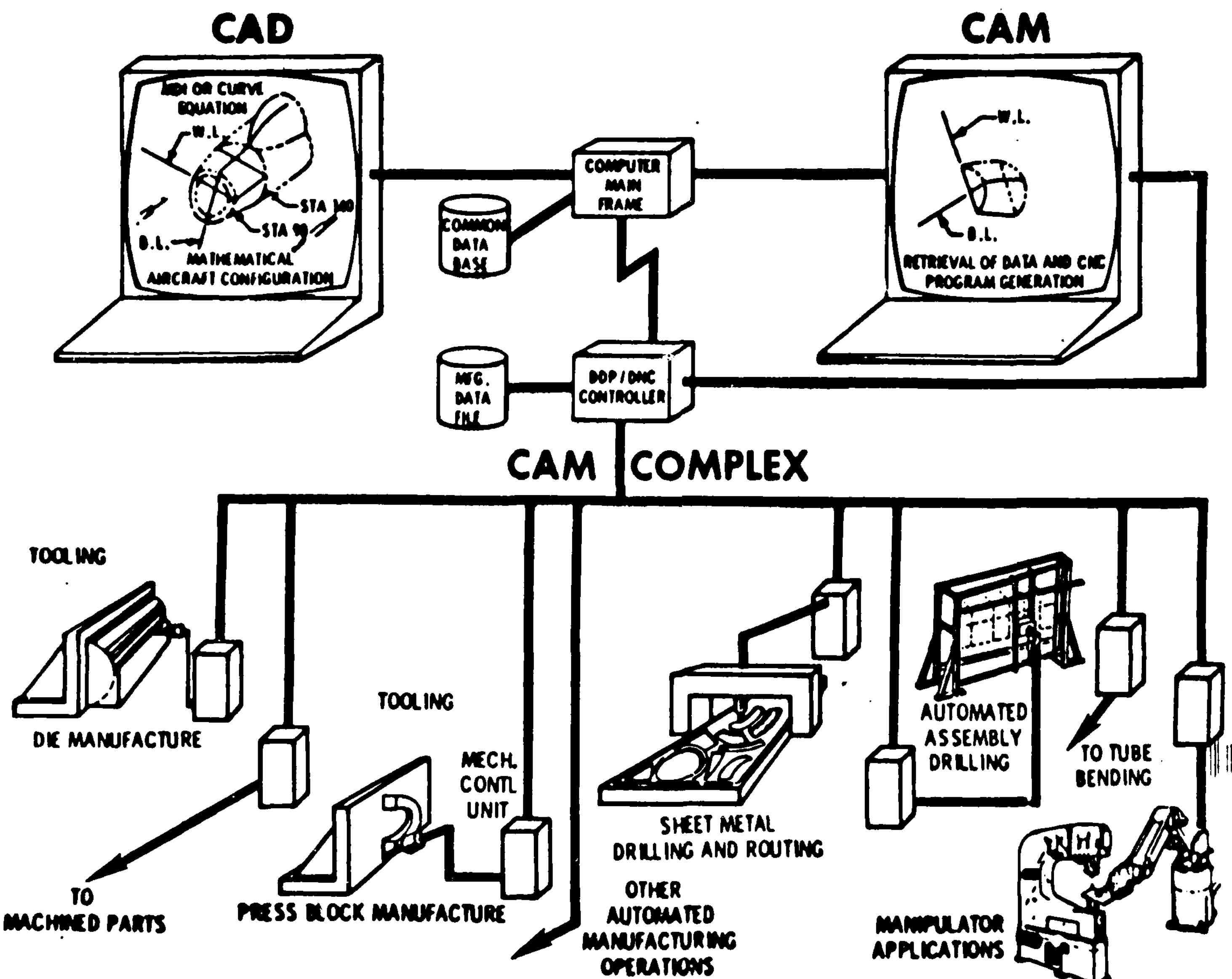
AXES ROTATIONS IN DEGREES

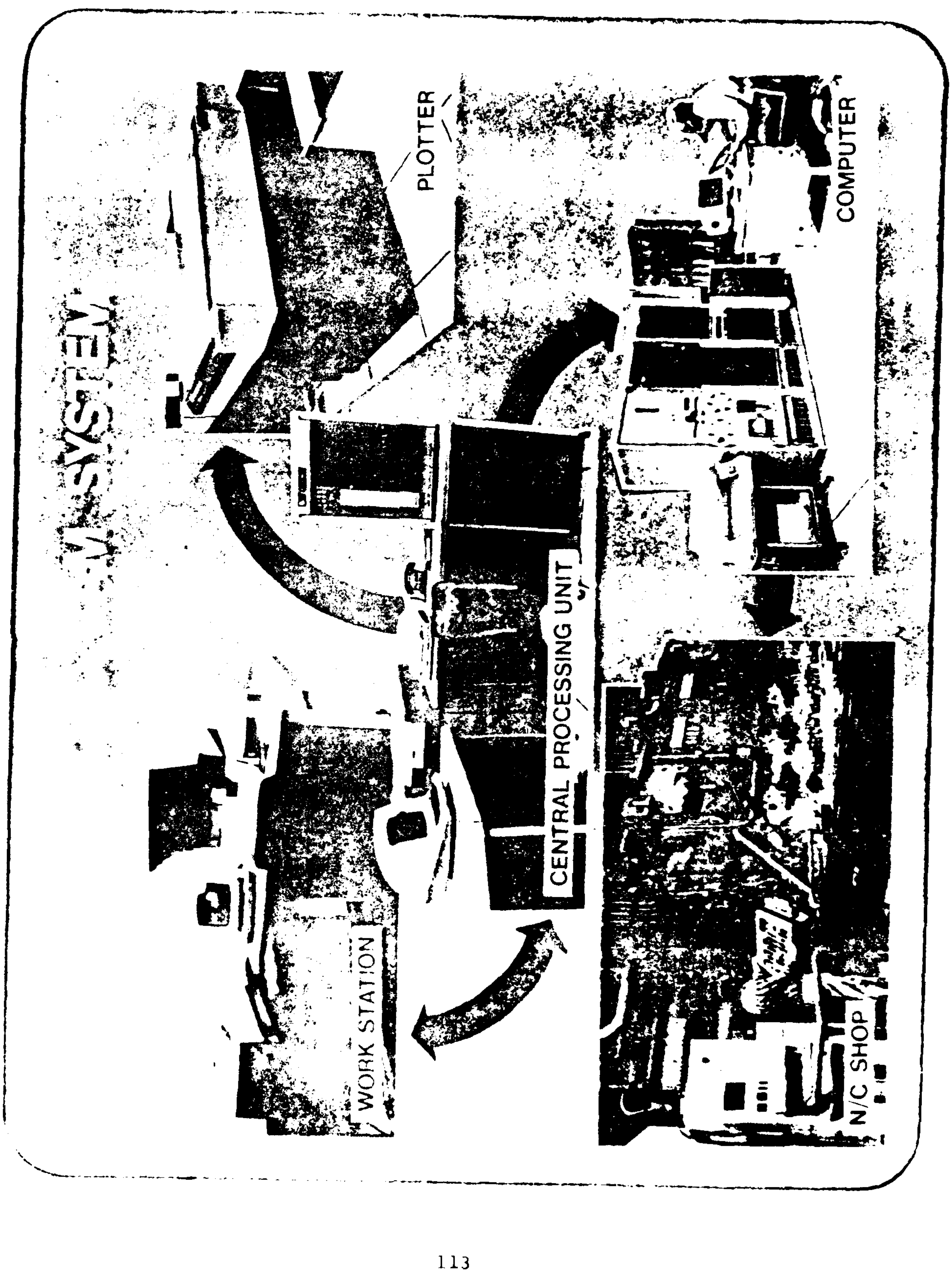
THETA(1)	THETA(2)	THETA(3)
-015.00	-015.00	-015.00




NORTH


ALTITUDE
AGL(FT)
1000
900
800
700
600
500
400
300
200
100
0
RANGE
TO
IMPACT
(FEET)
06248.
080
065
050
0
500
1000
AIR SPEED (KTAS)
VERTICAL
SPEED
FEET/MIN
+2500
+2000
+1500
+1000
+500
0
-500
-1000
-1500
-2000
-2500
TIME
TO
IMPACT
(SEC.)
014.
0152.


CAD
W.L.
STA 140
STA 90
B.L.
MATHEMATICAL
AIRCRAFT CONFIGURATION
CAM
W.L.
B.L.
RETRIEVAL OF DATA AND CNC
PROGRAM GENERATION
COMPUTER
MAIN
FRAME
COMMON
DATA
BASE
MFG.
DATA
FILE
DDP / DNC
CONTROLLER
CAM COMPLEX
TOOLING
DIE MANUFACTURE
TOOLING
MECH.
CONTL
UNIT
TO
MACHINED PARTS
PRESS BLOCK MANUFACTURE
SHEET METAL
DRILLING AND ROUTING
OTHER
AUTOMATED
MANUFACTURING
OPERATIONS
AUTOMATED
ASSEMBLY
DRILLING
TO TUBE
BENDING
MANIPULATOR
APPLICATIONS


SYSTEM
PLOTTER
COMPUTER
CENTRAL PROCESSING UNIT
WORK STATION
N/C SHOP

FRC CAD/CAM System

The heart of the CAD/CAM system is a Computervision Graphics System consisting of a Central Processing Unit, which controls all the logical and arithmetic functions, a disk drive which can store up to 300 million characters of immediately accessible filed information, and a magnetic tape drive, used as auxiliary storage of data not instantaneously retrievable.

Input to the CAD/CAM system is created at the Work Stations by a graphics operator using a light pen and digitizer and/or an alphanumeric CRT tele-display unit. The drawing resulting from this input, after processing by the Graphics System, is displayed on the graphics terminal at the Work Station. After revisions and corrections, as necessary, the finished drawing information is stored on the disc and may, as well, be plotted on the automatic plotter.

After the drawing is completed, the Numerical Controls programmer retrieves it for display on the graphics terminal and adds required numerical control machining instructions. This information can then be transmitted, via a physical link, to the Eclipse Computer, where a floppy disc is created which is used as input to the Numerical Control machines; the data is simultaneously stored on another disc connected to the Eclipse.

The Eclipse Computer is physically linked to the Vega III Controllers which automatically drive the machines in the Numerical Controls Shop. The operator of the machine in the shop can either call up the information directly from the Eclipse Computer or feed it into his machine from the floppy disc.

FRC CAD/CAM - PROJECT STATUS

FIRST COMPUTERVISION SYSTEM OPERATIONAL FEBRUARY 1980 (4 WORK STATIONS)

- MANAGER APPOINTED; SYSTEM OPERATORS HIRED
- 3 WORK STATIONS ADDED TO SYSTEM - 1 JULY 1980

SECOND COMPUTERVISION SYSTEM OPERATIONAL JANUARY 1981

- REQUIRED TO SUPPORT 340 COMMUTER PROJECT ACTIVITIES IN 1981
- ADDITION OF 3 WORK STATIONS - TWO SYSTEMS EACH WITH 5 WORK STATIONS
- ADDITIONAL SYSTEM OPERATORS BEING HIRED

DATA COMMUNICATIONS LINK BETWEEN CV SYSTEM AND CORPORATE 4341 - 24 APRIL 1981

TRAINING ACTIVITIES

- 757 TRAINING COMPLETED 1 JUNE 1980 - N/C, LOFT, TOOL DESIGN PERSONNEL
- SF340 TRAINING COMPLETED 1 OCTOBER 1980 - ENGINEERING PERSONNEL
- TOTAL OF 41 PERSONS (24-ENG'G, 17-MFG) TRAINED AS CV SYSTEM USERS
- TRAINING RESUMED 1 APRIL 1981

PRODUCTION ACTIVITIES

- INITIATED 1 JUNE 1980
- N/C, LOFT, TOOL DESIGN, DESIGN ENGINEERING
- 757, SF340, A-10, NGT PROJECTS SUPPORTED
- 120 WORK-STATION HOURS/DAY CURRENTLY SCHEDULED

CAD/CAM COORDINATING COMMITTEE ORGANIZED

- REPRESENTATIVES FROM ALL USER DISCIPLINES
- MEETINGS HELD WEEKLY

FRC CAD/CAM - FUTURE PLANS

PRODUCTION AND TRAINING ACTIVITIES

- CONTINUED SUPPORT OF 757, A-10, NGT PROJECTS IN 1981
- INCREASED SUPPORT OF SF340 COMMUTER PROJECT
- TRAINING OF CV USERS TO CONTINUE THRU 1981

FUTURE CAD/CAM OPTIONS

- COMPUTERVISION
  - 4 ADDITIONAL SYSTEMS BETWEEN 1981 AND 1985
  - TOTAL OF 20 ADDITIONAL WORK STATIONS
- LOCKHEED CADAM ON FRC ENGINEERING COMPUTER
  - 5 - 10 WORK STATIONS OPERATING IN LATE 1981
  - ADDITIONAL WORK STATIONS AVAILABLE IN 1982-3
  - USED FOR SUPPORT OF PROJECTS OTHER THAN SF340

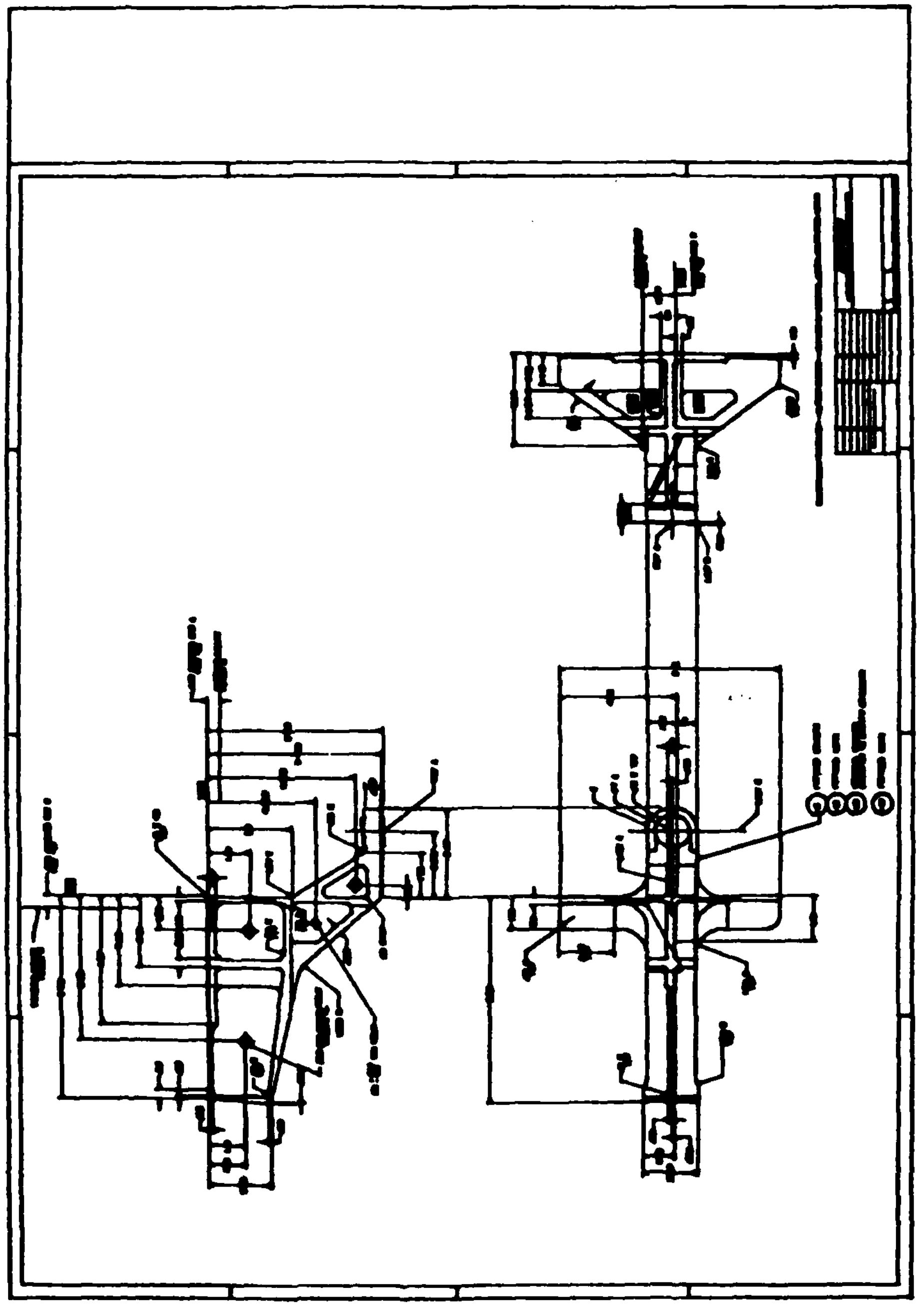
CADAM - FUTURE FRC CAD/CAM OPTION

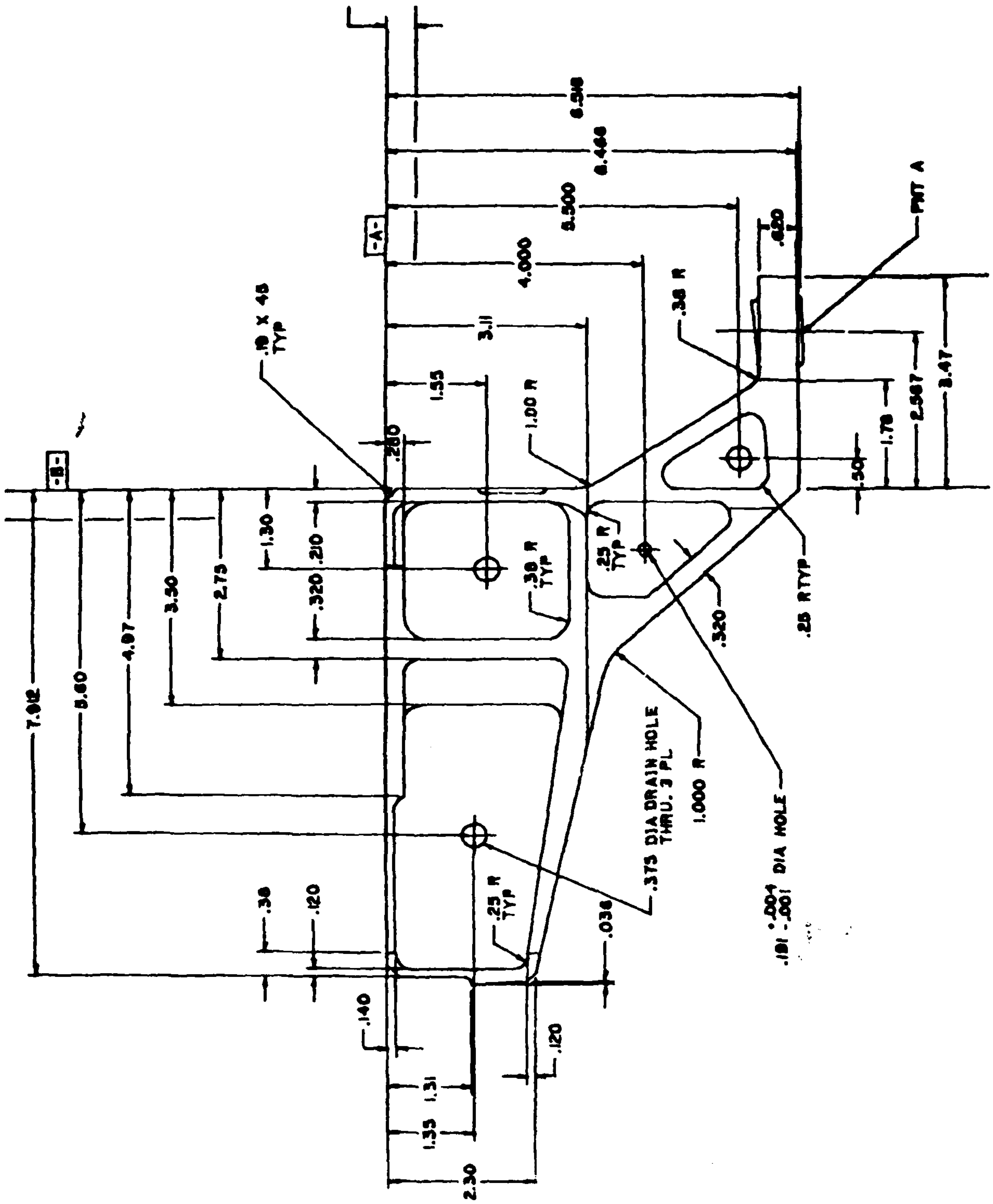
COMPUTER - GRAPHICS AUGMENTED DESIGN AND MANUFACTURING (CADAM)

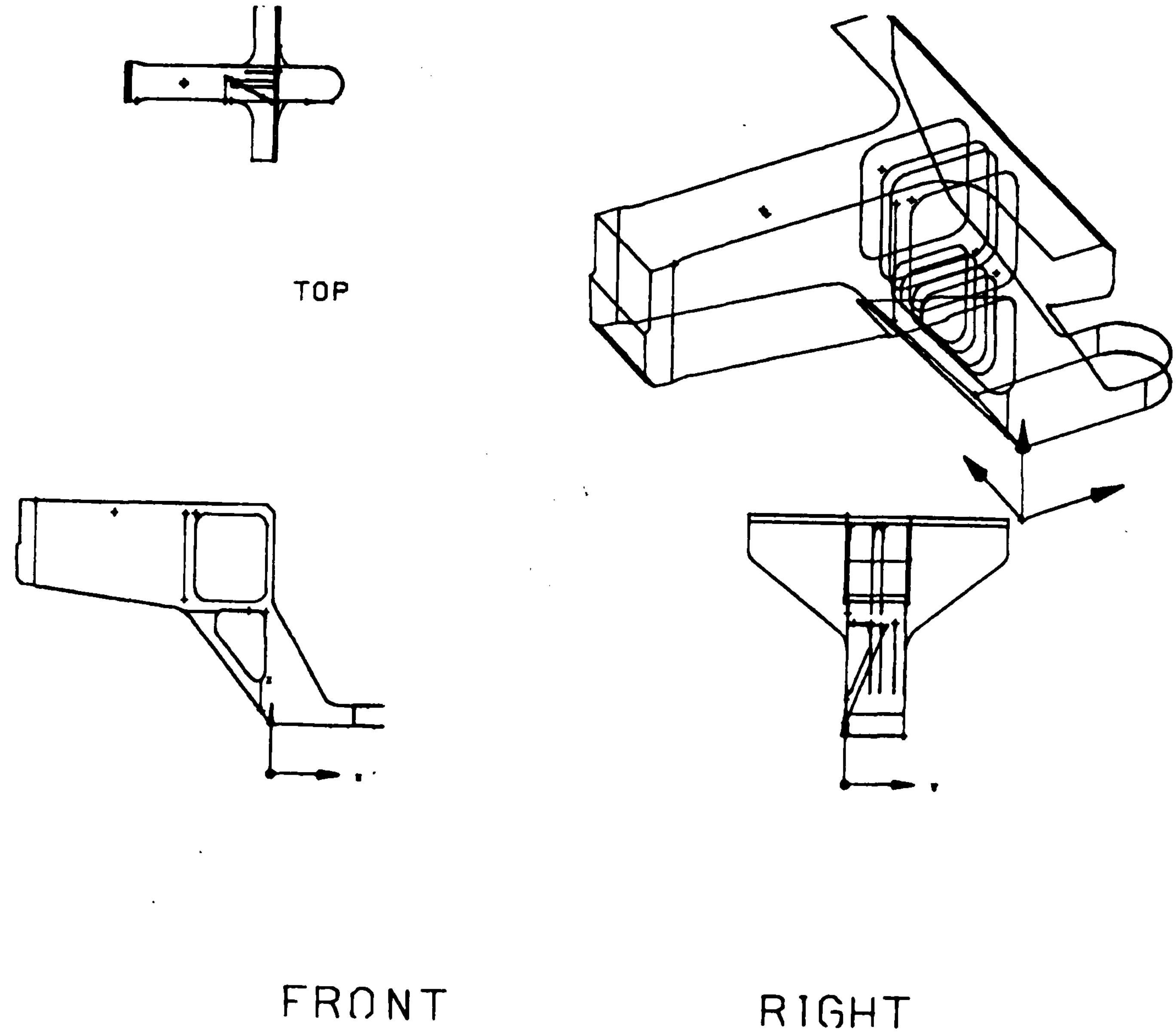
- SOFTWARE PACKAGE DEVELOPED & MAINTAINED BY LOCKHEED
- MARKETED BY IBM
- ADDITIONAL IBM SUPPORT
    - NUMERICAL GEOMETRY SYSTEM (NGS) - ALLOWS 3D N/C CAPABILITY
    - SOFT COPY - PRODUCES RAPID COPIES OF SCREEN DISPLAYS
- RUNS ON MAINFRAME COMPUTER USING REFRESH GRAPHICS TERMINALS
- CONSIDERED TECHNICALLY ACCEPTABLE BY FRC PERSONNEL

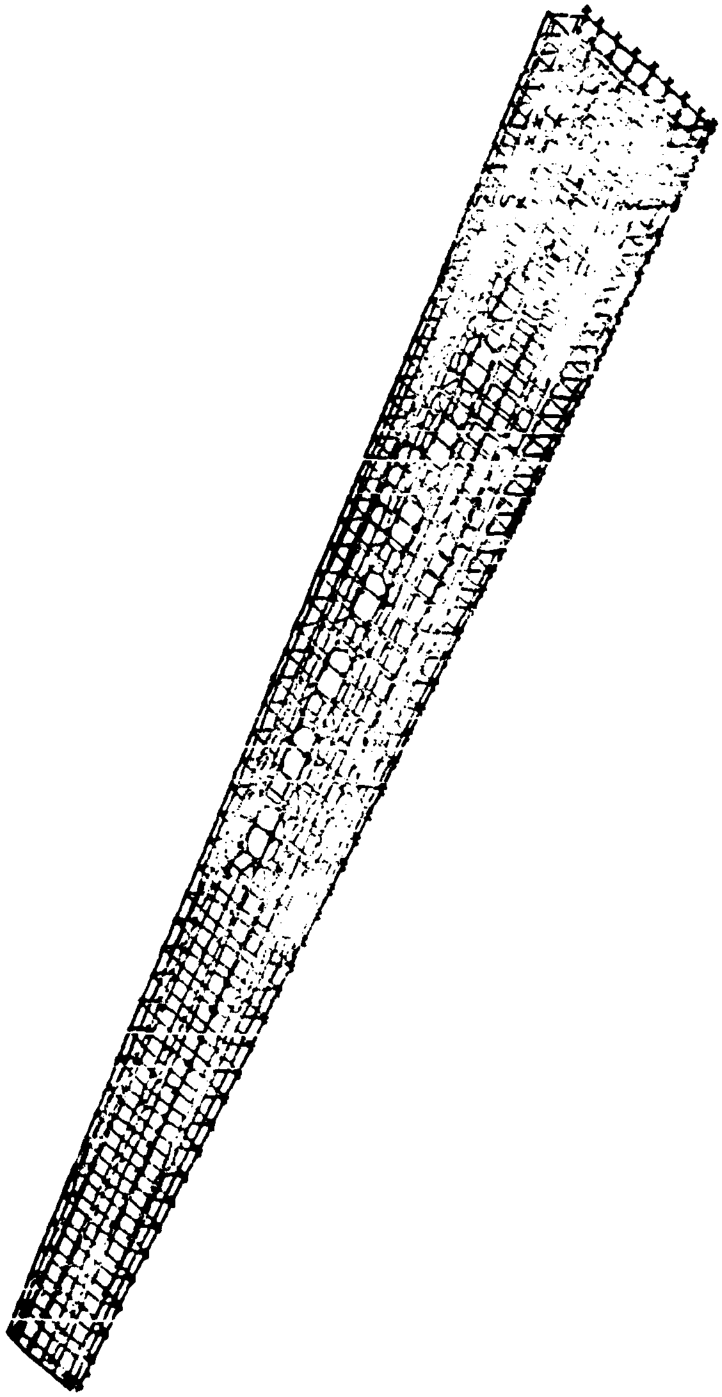
CADAM INVESTIGATION AT FRC (1981)

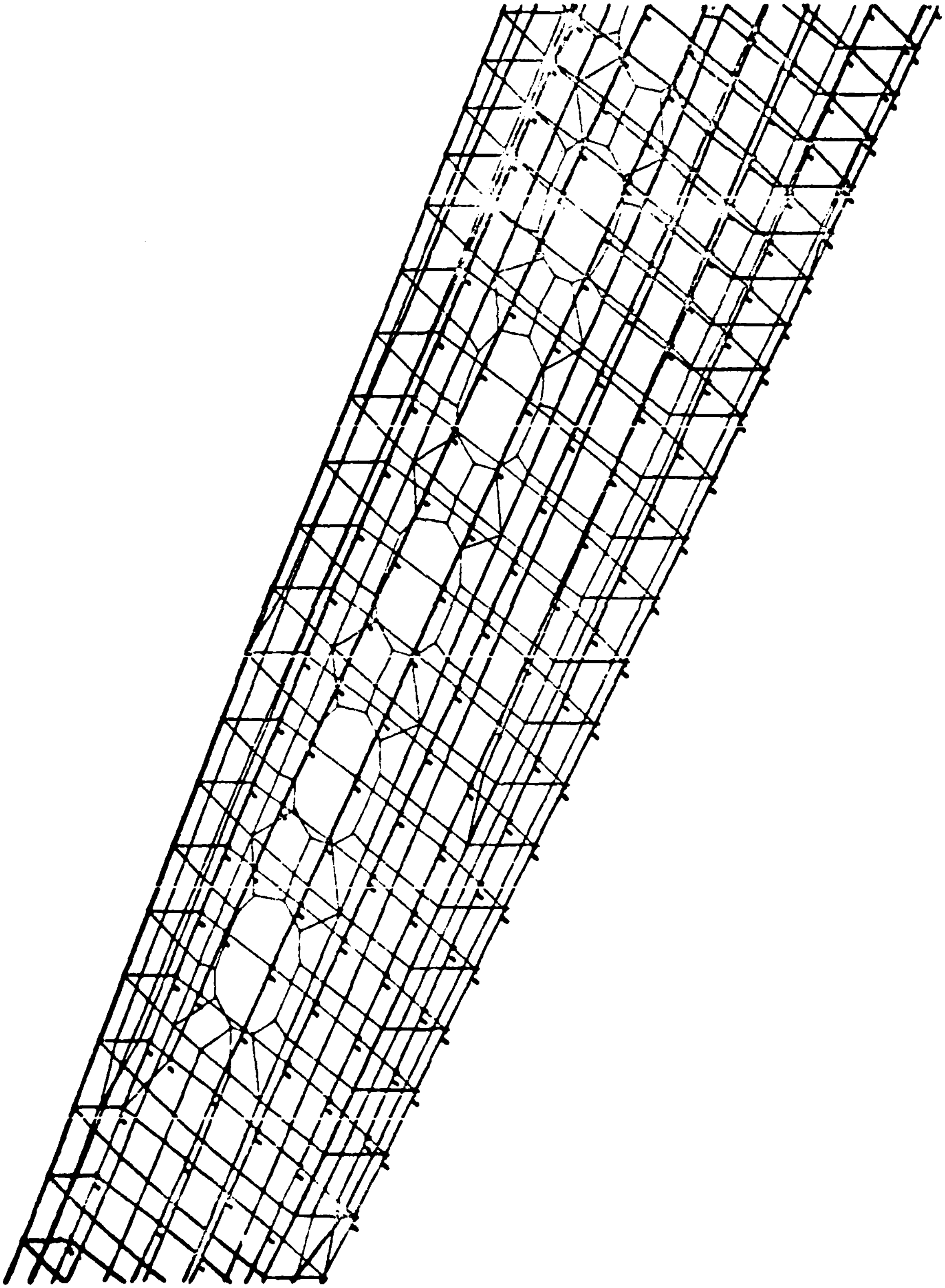
- PILOT TEST PROGRAM AT FRC - 2 TERMINALS FOR 6 MONTHS
- STUDY TO BE COMPLETED (OCT 1981) PRIOR TO ACQUISITION OF ADDITIONAL HARDWARE

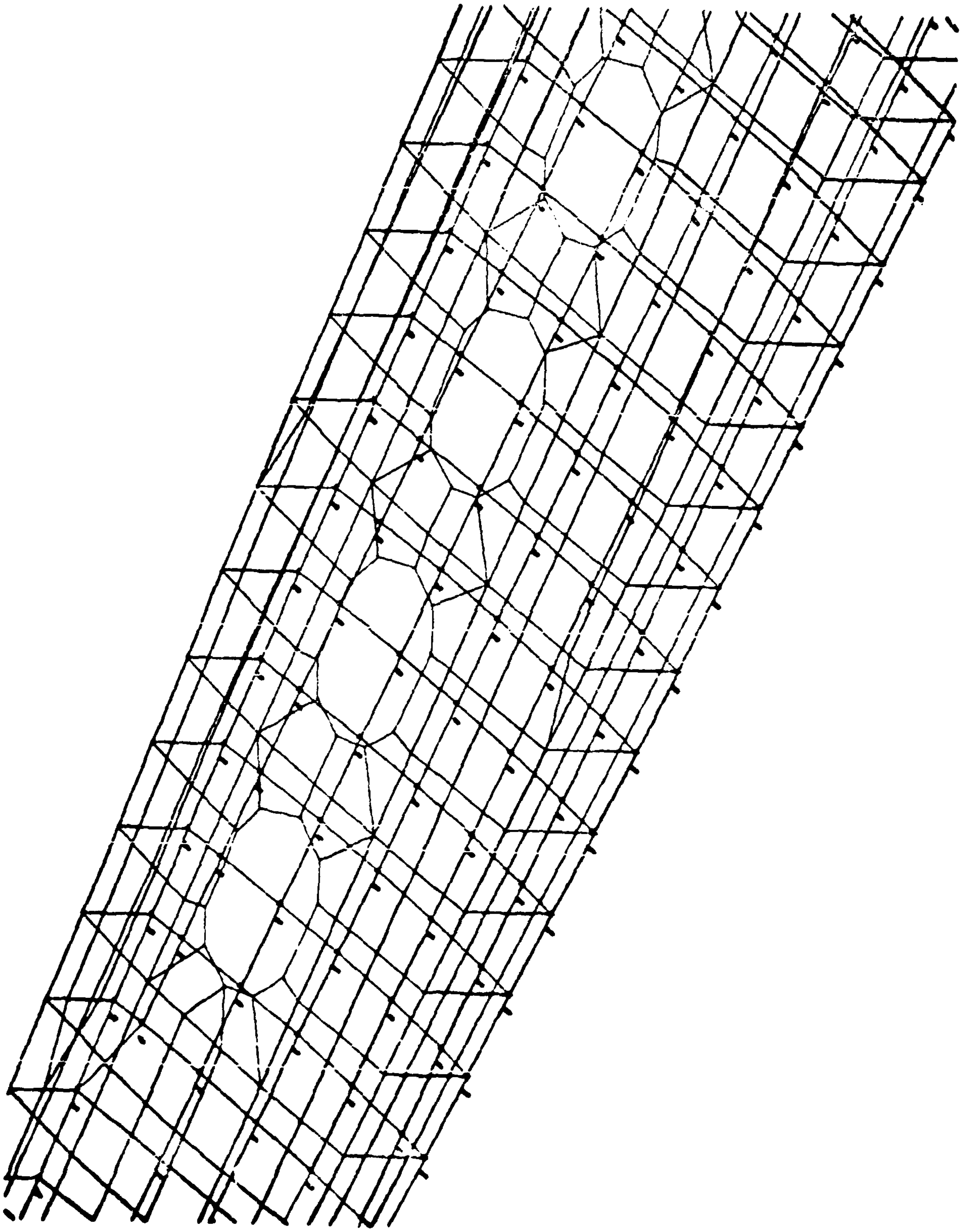


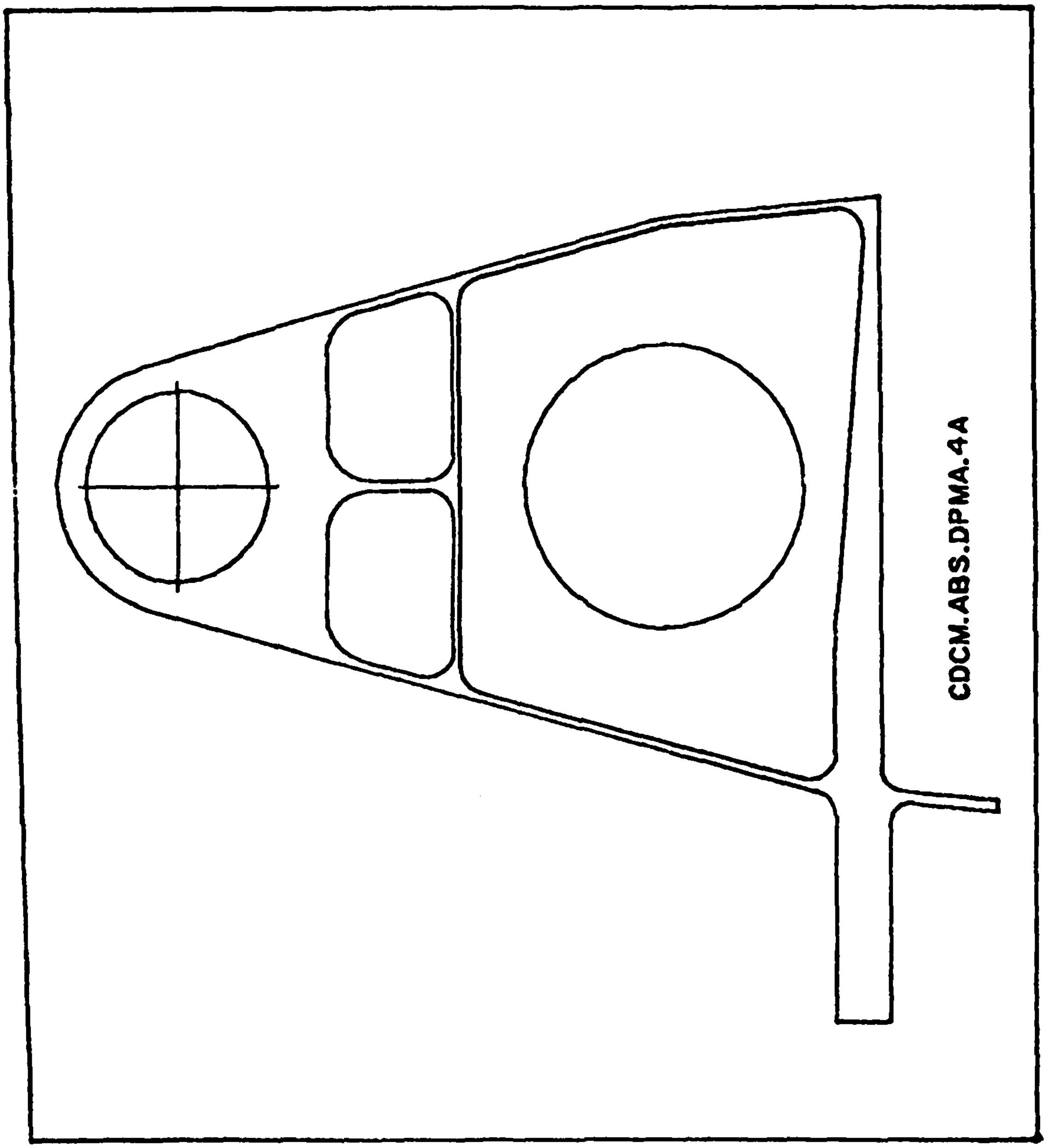

-A-
-B-
6.516
6.446
5.500
4.000
3.11
1.55
.280
.10 X 45
TYP
.620
.38 R
1.00 R
PNT A
3.47
2.567
1.78
.50
.25 R
TYP
.320
.25 RTYP
.38 R
TYP
1.30
.210
.320
2.75
3.50
4.97
5.60
7.912
.375 DIA DRAIN HOLE
THRU. 3 PL
1.000 R
.181 +.004 -.001 DIA HOLE
.25 R
TYP
.036
.38
.120
.140
1.31
1.35
2.30
.120

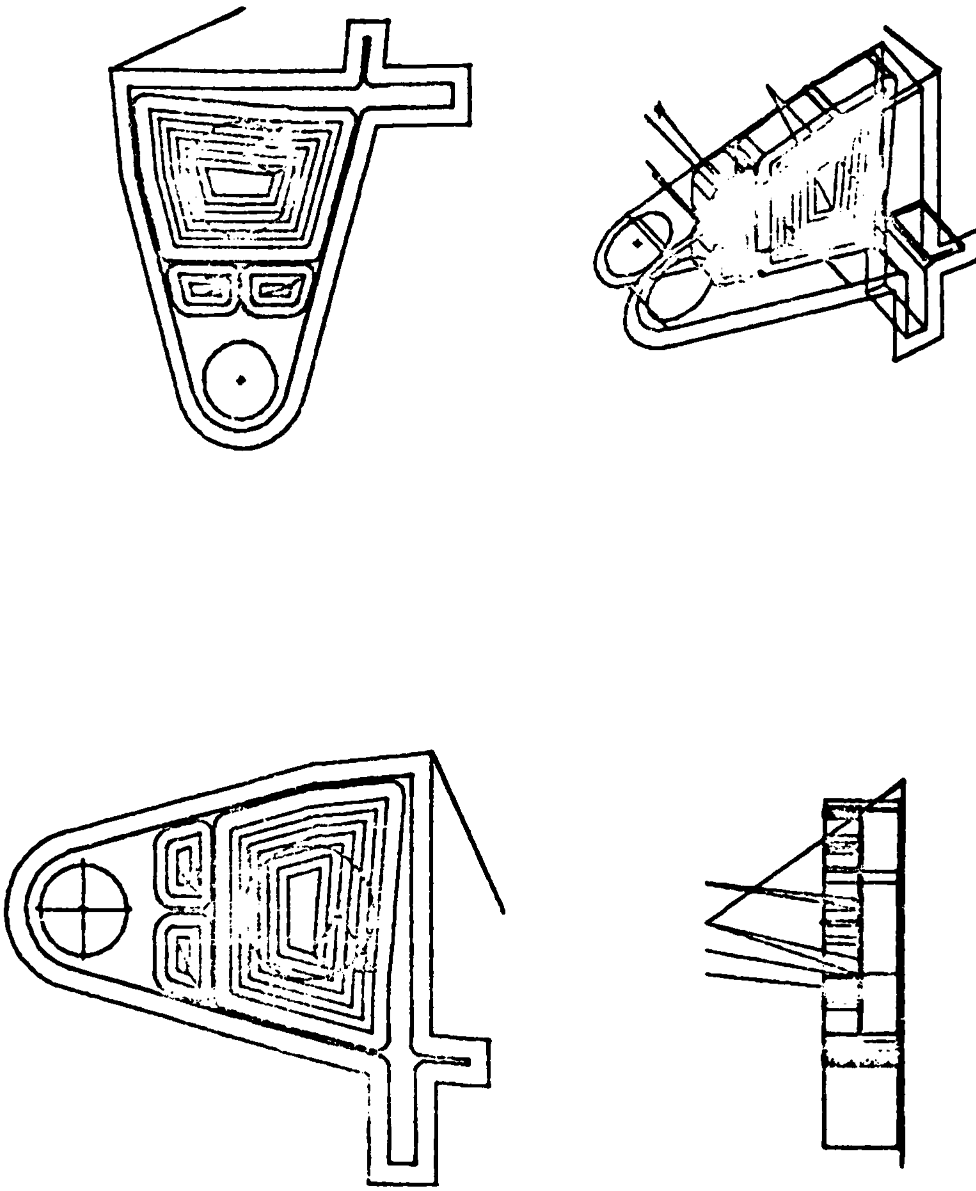

TOP
FRONT
RIGHT



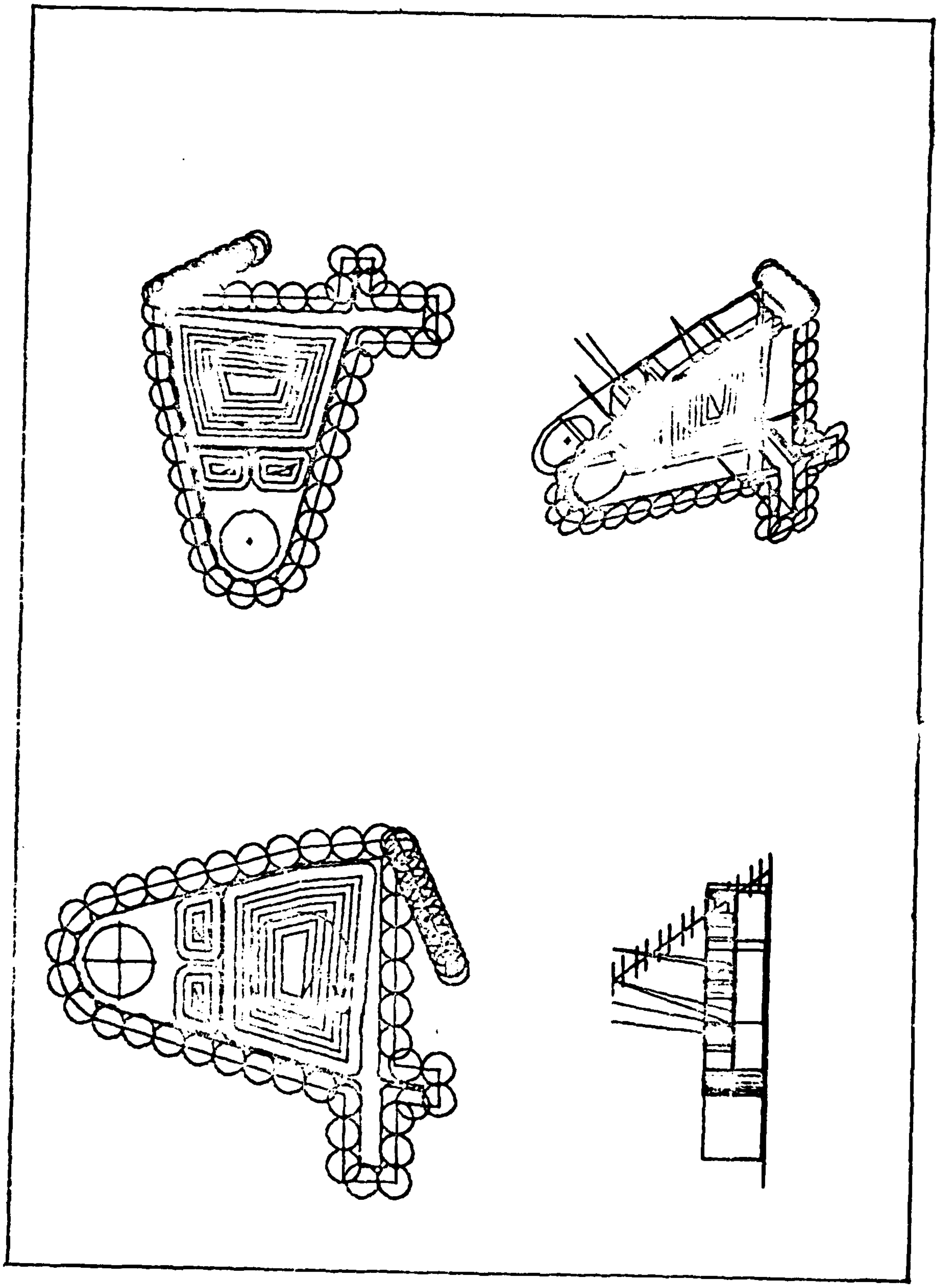





CDCM.ABS.DPMA.4A



CDCM.ABS.DPMA.4B



PRIME - DATA BASE SYSTEM DEVELOPMENT

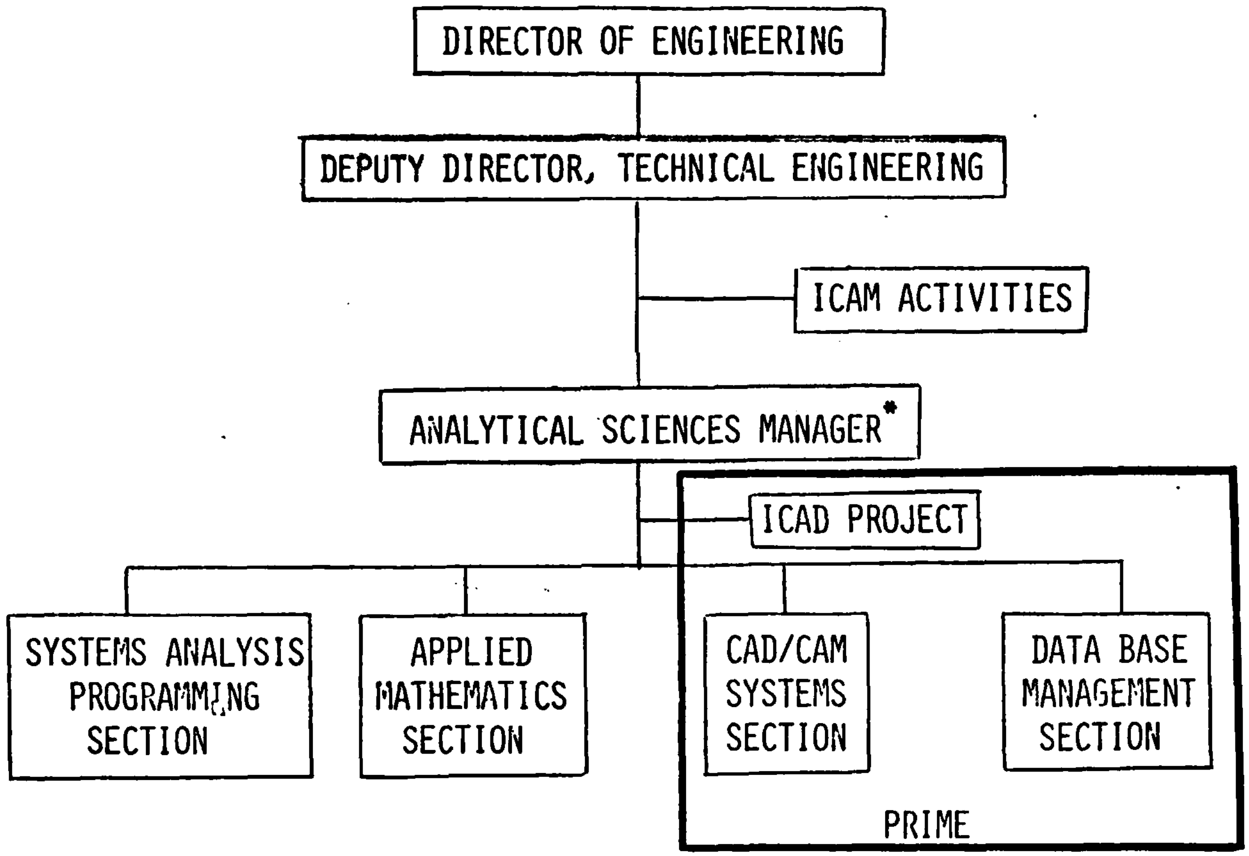
STATUS:

- ICAD FILE DIRECTORY SYSTEM DEVELOPED & IMPLEMENTED
  (INITIAL PRIME DATA MANAGEMENT CAPABILITY)
- REQUIREMENTS FOR COMPUTER PROGRAM CONTROL SYSTEM ESTABLISHED
- INVESTIGATION OF APPLICABILITY OF DATA BASE SYSTEMS FOR PRIME-ON-GOING

FUTURE PLANS:

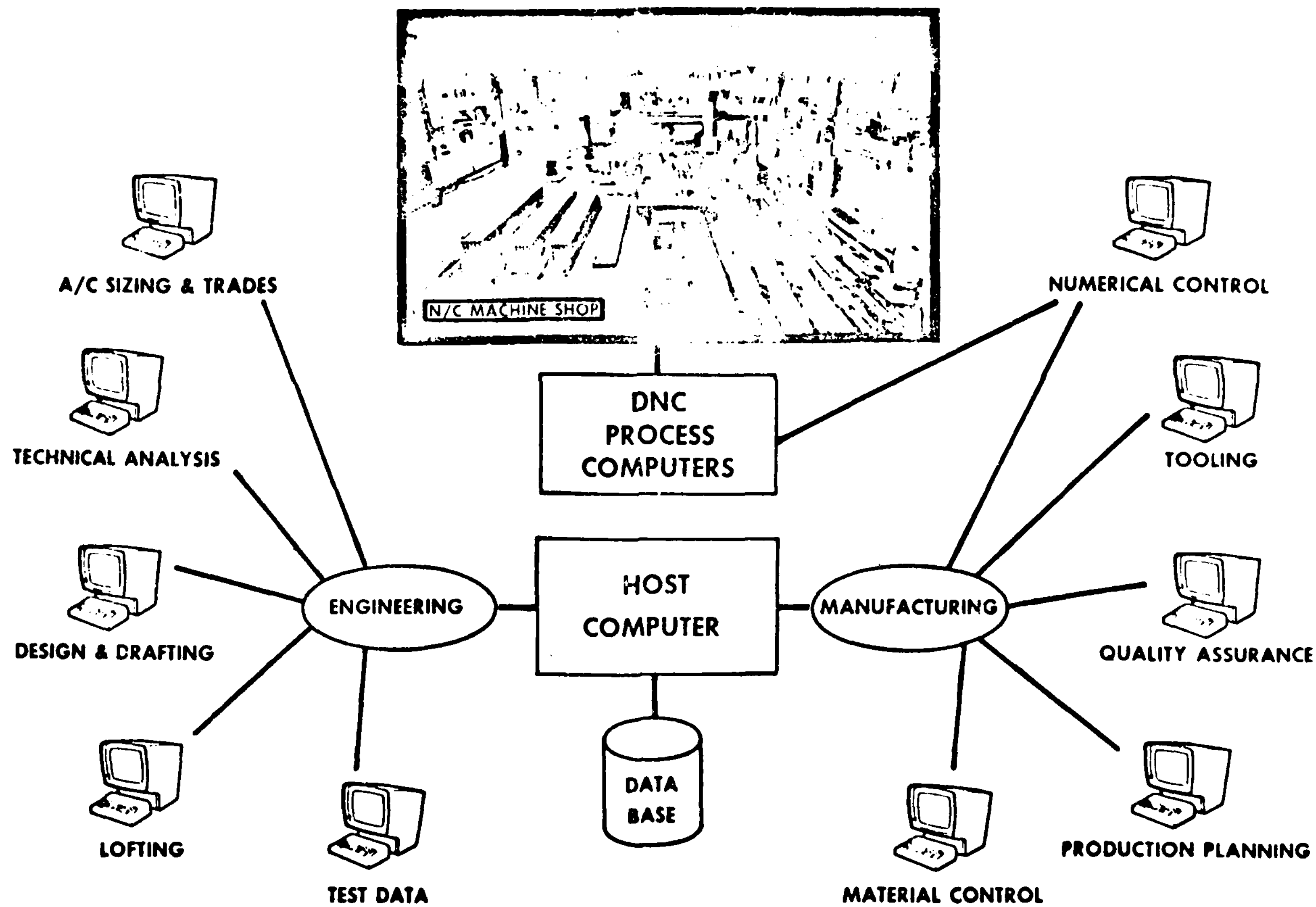
- IMPLEMENT COMPUTER PROGRAM CONTROL SYSTEM (1981)
- DEVELOPMENT OF ENGINEERING DATA DICTIONARY
- CONTINUE INVESTIGATION OF DATA BASE SYSTEMS FOR PRIME USE
- TEST & EVALUATE IPAD-DEVELOPED DATA BASE SYSTEM (RIM; IPIP)
- INSTALL AND IMPLEMENT DATA BASE MANAGEMENT SYSTEM FOR PRIME

PRIME IN THE STRUCTURE OF THE FRC ENGINEERING ORGANIZATION



* ALSO PRIME PROJECT MANAGER

THE ULTIMATE SYSTEM



CAD AND ADVANCED COMPOSITE AIRCRAFT ELECTROMAGNETIC PROTECTION

John A Birken
Naval Air Systems Command
Washington, D.C.

Robert F. Wallenberg
Syracuse Research Corp.
Syracuse, New York

CAD AND ADVANCED COMPOSITE AIRCRAFT ELECTROMAGNETIC PROTECTION

John A. Birken
Naval Air Systems Command
Washington, D.C.

Robert F. Wallenberg
Syracuse Research Corp.
Syracuse, New York

New materials, aircraft designs, and high-level threats are rapidly emerging which necessitate that future aircraft satisfy mission requirements from the onset of design. Mission requirements now include surviving increasing threats using low-level solid-state equipment, which comprise fly-by-wire control systems and composite materials that generally provide poor electromagnetic shielding. The need to know how each of the aircraft design disciplines interact upon each other has become essential. The Navy cannot afford to build aircraft, test them, and then correct for design defects not considered at the onset of the design. Furthermore, the ability to evaluate performance and cost impact from rapidly changing technologies and the change in military posture they necessitate has extremely high value.

These concepts give rise to the idea of using computer-aided technology in all aspects of aircraft design to arrive at a "total systems approach" to the optimization of aircraft design from structural, material, and electromagnetic viewpoints. This will avoid undue concentration on isolated aspects of the design, thereby producing greater total savings.

Two aircraft containing significant amounts of composite material, the YAV-8B and F-18 are shown in Figures 1 and 2. Other composite material platforms under development include the Advanced Attack Fighter, the MX missile, and the Advanced Composite Airframe Program (ACAP).

A general composite material can be defined as a man-made combination of two or more chemically distinct materials, with a distinct interface separating them, and created to obtain properties unachievable by the individual elements alone. Examples include graphite/epoxy, boron/epoxy, and Kelvar.

The increased use of composite materials in aircraft structures and subsystems significantly increases electromagnetic effects on avionics subsystems performance. The resulting avionics/computer failures jeopardize the pilot's life and the safety/mission of the aircraft, helicopter, or missile.

Cross-discipline issues to be considered in the use of composites are illustrated in Figure 3. For example, covering graphite/epoxy with aluminum foil can solve the electromagnetic shielding, lightning protection, water vapor absorption, and heating effects problems but not the corrosion, lifetime degradation, or maintenance and repair problems. Using a glass coating on graphite/epoxy with an aluminum facing, such as in Thorstrand material, solves the corrosion problem. However, the weight penalty may be too severe and the aluminum coating may not be thick enough or sufficiently conducting to provide electromagnetic protection. Some means of retarding lifetime degradation and good maintenance and repair must also be provided.

Similar interdiscipline concepts carry over into joint construction. To prevent corrosion, joints are bonded with nonconducting adhesive and anodized nonconducting fasteners, but this makes an electrically porous joint. For an electrically tight joint, conducting adhesive should be used together with fasteners that make good electrical contact.

Basic to an integrated approach is the design, control, and use of a common data base that reduces redundant efforts, assures validity of data, and shortens calendar time. This common data base is available in the NASA Structural Analysis Program (NASTRAN) geometric data base and other currently available computer-aided design programs used by the aircraft industry, such as in survivability/vulnerability studies for the F-14, shown in Figures 4 and 5. They have been extensively used in the design of the Navy F-18 aircraft and are currently being used in the AV-8B aircraft design. The geometrical data base available on the F-18 and AV-8B programs can be combined with existing electromagnetic analysis codes to evaluate the electromagnetic impact provided by new materials and structures. The results of the extensive electromagnetic testing of the F-18 and AV-8B provide an empirical basis to corroborate the integrated structural, material, and electromagnetic analysis codes with experiments already performed. NASTRAN or other CAD routines will serve as a means of communicating the structural material and electromagnetic properties of aircraft to the design engineer from inception of aircraft design.

The finite element model in Figure 6 is an example of an aircraft design using CAD techniques. The aft fuselage section is comprised of a non-conducting dielectric composite (Kelvar) with a protective layer of Thorstrand (developed by MB Associates). This section is presently

being tested at Sandia Laboratories with radiation from 10 kHz to 10 GHz in the test facility of Figure 7 and current injection from 1 kHz to 5 MHz. Previously, Kevlar panels with aluminum flame spray, wire grid mesh, Thorstrand, and silver paint were similarly tested using the box shown in Figure 8. It is shown using a triangular patch model in Figure 9.

To synthesize designs, the surface current J_s needs to be calculated as shown in Figure 10, which depicts a cross section of the General Dynamics F-16 graphite/epoxy non-aerodynamic forward fuselage. Here, we break the aircraft shape into finite sections and use the Method of Moments (MOM) or Finite Element Codes (FEC). Such capability is being exercised on the Naval Air Systems Command computer facility to evaluate electromagnetic performance of new aircraft designs and of significant existing aircraft modifications.

A MOM program based on triangular patch expansion functions is presently being implemented at the Naval Air Systems Command. Its output capabilities will include those shown in Figures 11 and 12. The results can be compared with the measured cases shown in Figures 13 and 14.

Figures 15 to 17 illustrate the electric shielding inside a two-dimensional graphite/epoxy F-16 forward fuselage. Figures 16 and 17 illustrate the effect of a window. A number of cases were run illustrating that: (a) for the TM case (E_z parallel to z), as frequency is lowered, the effect of the window on degradation of shielding is minimized, (b) the effect of a window on the TE case (H_z parallel to z) drastically reduces shielding effectiveness, and (c) TE shielding was virtually nil below 10 kHz.

To synthesize the electromagnetic protection required by advanced composite material aircraft, helicopters, and missiles, it is necessary to generate the transfer functions D(f) and T_1(f) through T_5(f) of Figure 18 for different airframes and avionic systems. Knowledge of D(f) and T_1(f) through T_5(f) allow evaluation of voltages and currents which result from the different threats.

The frequency spectrum for nuclear, lightning, and projected laser threats is shown in Figure 19. This chart shows the high intensity of lightning at low frequencies and that the nuclear pulse has a higher frequency content.

Graphite/epoxy is the best conducting composite material with a conductivity of 10^4 mhos/m, while Kelvar is a nonconducting dielectric composite material with a conductivity of 6×10^{-9} mhos/m. A measure of material shielding is given by the term transfer impedance, given for all frequencies by

$$Z_{st} = E_t/J_s = \eta \operatorname{csch}(\gamma d) \qquad (1)$$

where $\eta = j\omega\mu/\sigma$ is the intrinsic impedance of the shield, $\gamma = j\omega\mu\sigma$ is the propogation factor, and d is the shield thickness. Figure 20 shows the surface transfer impedance for aluminum graphite/epoxy, and boron/epoxy in the same thickness as 8-ply graphite/epoxy (0.001069 m). Figure 21 plots the low frequency asymptote of $T_1(f)$ in bar chart form. The figure illustrates the shielding effectiveness of the various foils, on an absolute scale including an 8-ply laminate of graphite/epoxy. Figure 20 illustrates the improvement in transfer impedance as frequency increases. Designs with the number from Figure 21 reflect requirements imposed by the very low frequency content of lightning and the nuclear pulse.

Figures 22 through 27 are descriptions of some of the remaining transfer functions, $T_2(f)$ through $T_5(f)$.

Predicted values of voltage and current resulting from full-thrust lightning and nuclear pulses on an all composite aircraft are shown in Figure 28. These scale remarkably well with measured values gathered to date.

Figure 29 shows the improvement of various protective coatings on 8-ply graphite/epoxy. The plot is on an absolute scale with all coating thicknesses fixed at 4 mils. For the coatings considered, the effect of the coatings dominates the shielding of the graphite/epoxy.

The improvement that protective coatings provide relative to 8-ply graphite/epoxy is just the ratio of their transfer impedance, or

$$\text{Improvement} = \frac{V(G/E)}{V(\text{coating})} = \frac{Z_{st}(G/E)}{Z_{st}(\text{coating})}$$

$$= \frac{1/\sigma_{G/E} d_{G/E}}{1/\sigma_c d_c} = \frac{\sigma_c d_c}{\sigma_{G/E} d_{G/E}} \qquad (2)$$

A non-conducting layer between the conducting coating and graphite/epoxy is assumed to prevent corrosion.

The weight penalty paid by coating with 4 mils of various foil meshes and flame spray in shown in Figure 30. This is based on 100 ft^2 of coating, which is the estimated surface area of the AV-8B graphite/epoxy forward fuselage.

The combined measure of shielding and weight penalty for the various coatings is given in Figure 31. It is defined as

$$\text{Figure of Merit} = \frac{\text{Improvement}}{\text{Surface Density}} = \frac{Z_{st}(G/E)/Z_{st}(\text{coating})}{\rho_s} \tag{3}$$

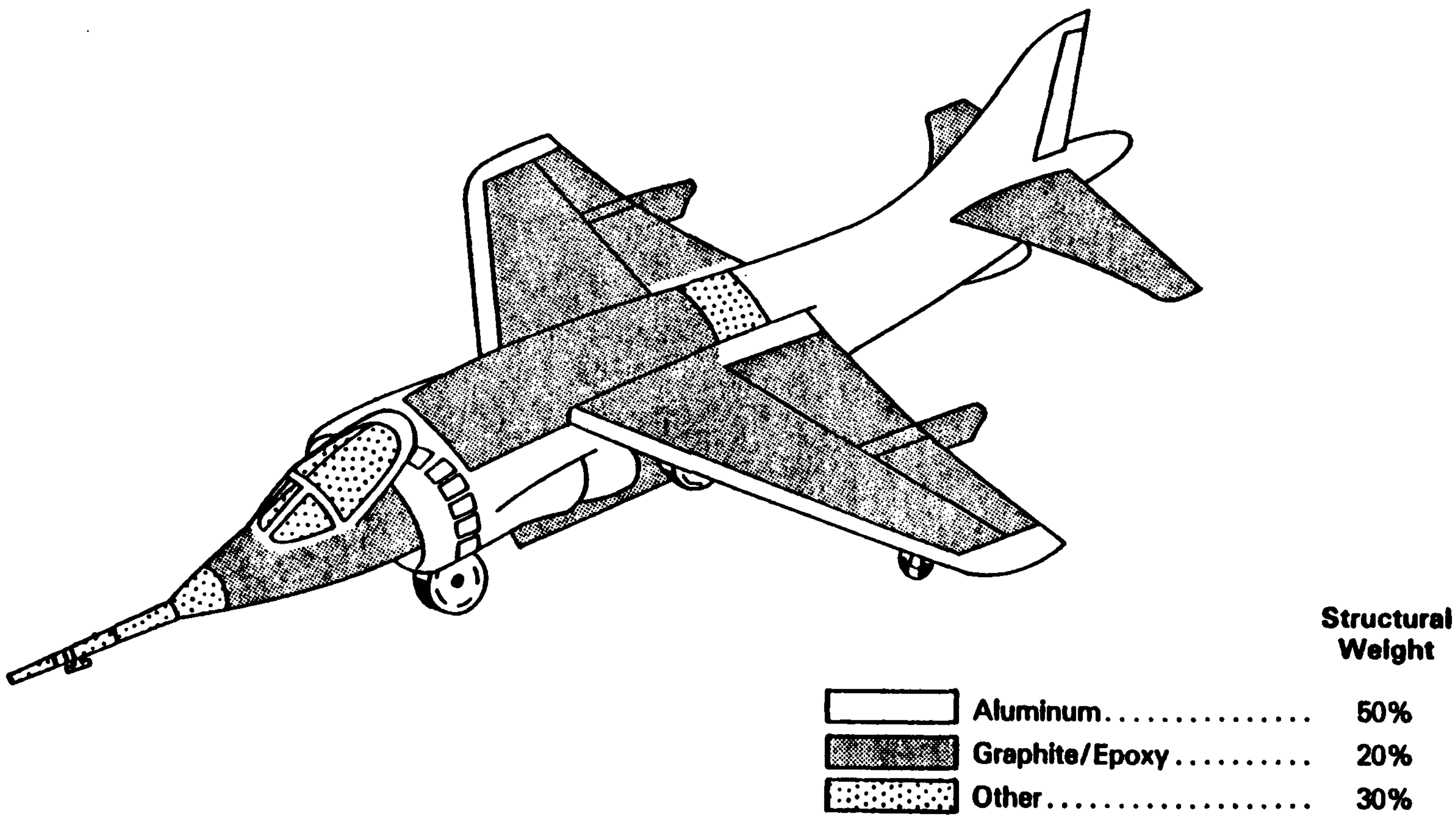


Figure 1. YAV-8B Composites Applications

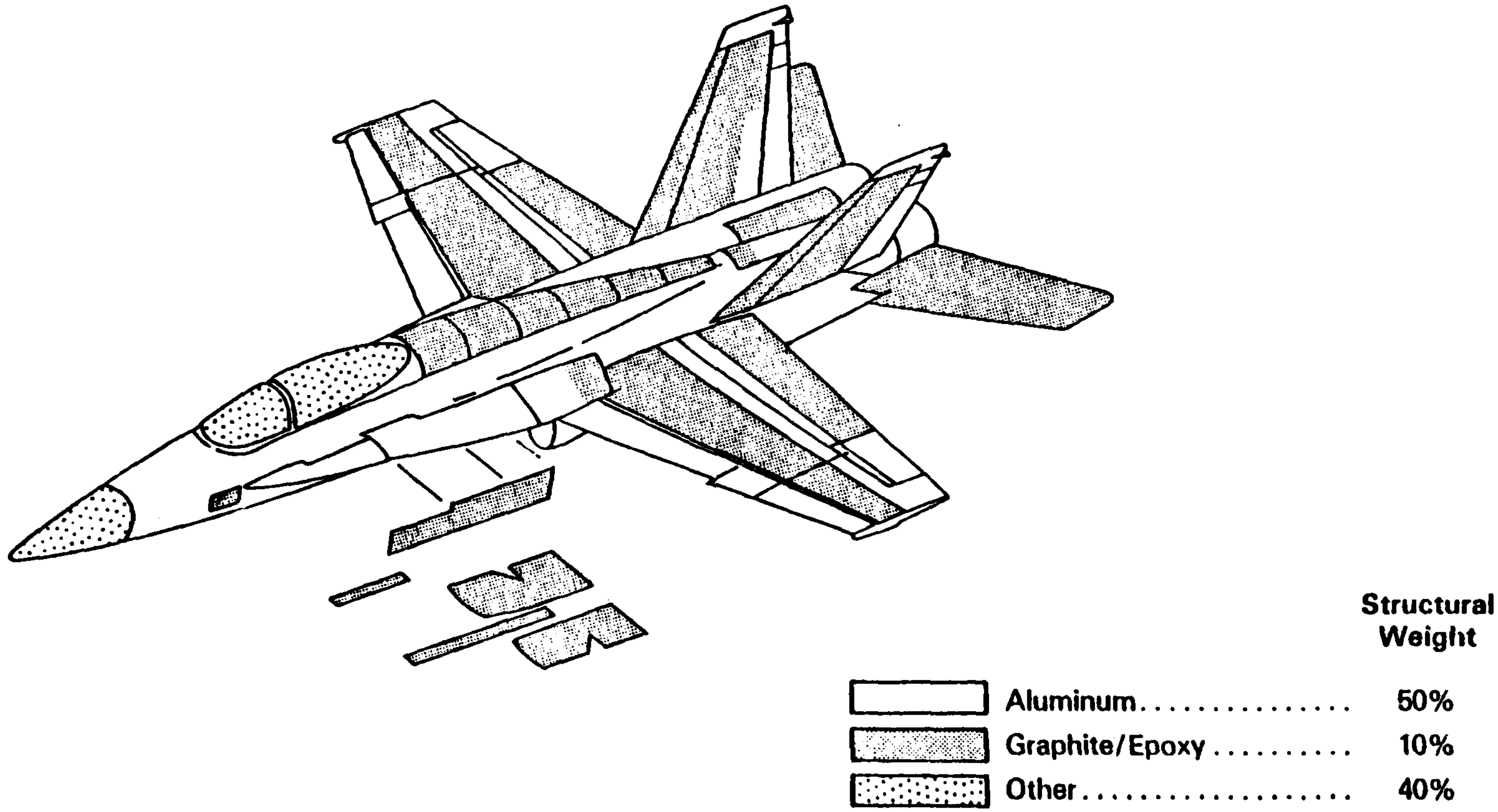


Figure 2. F-18 Composites Application

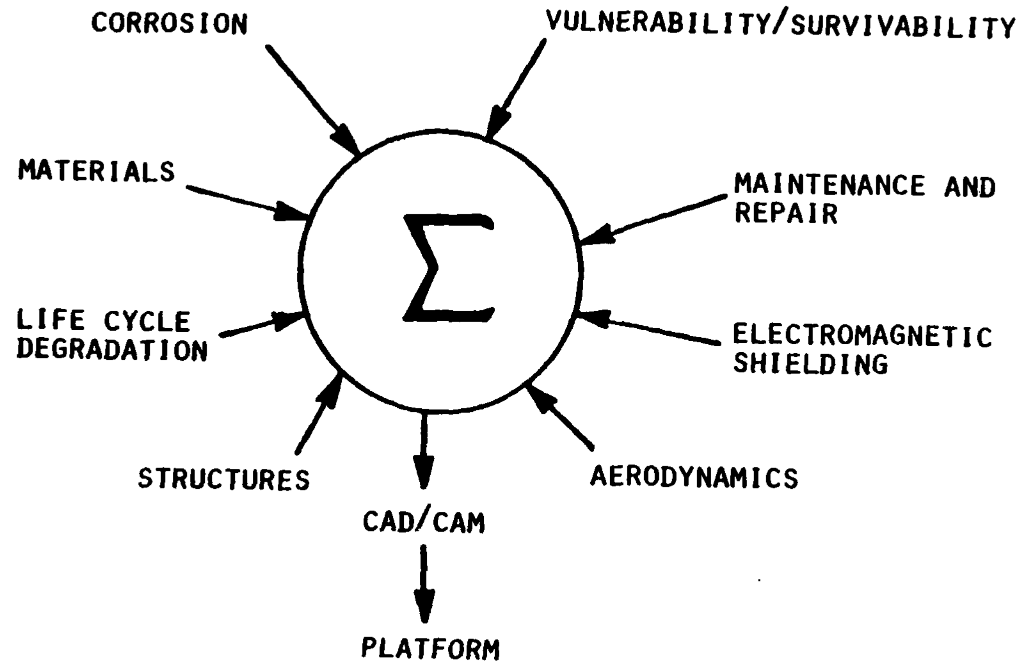


Figure 3. Synergize Platform Disciplines

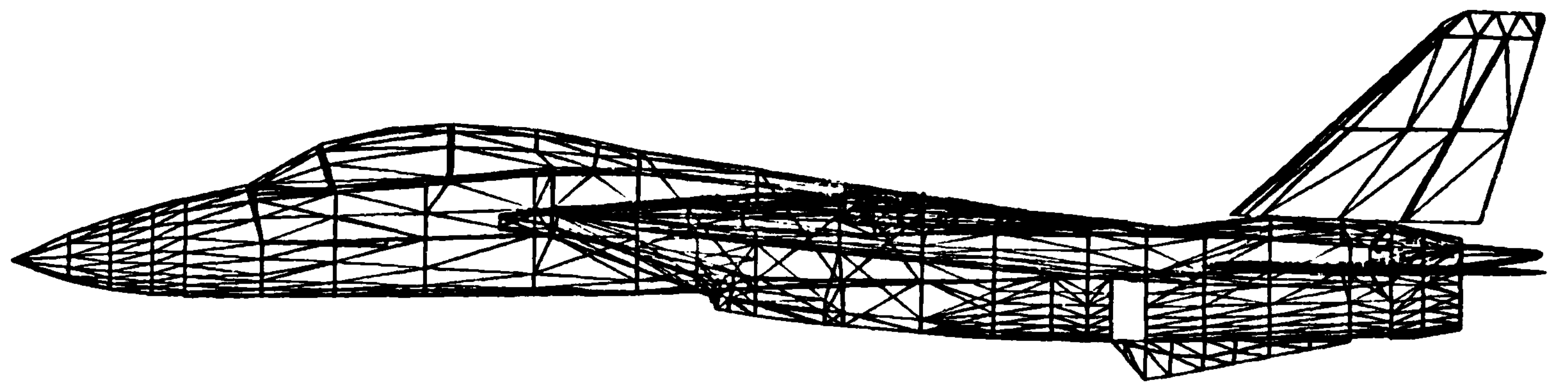


Figure 4. F-14 Survivability/Vulnerability Model

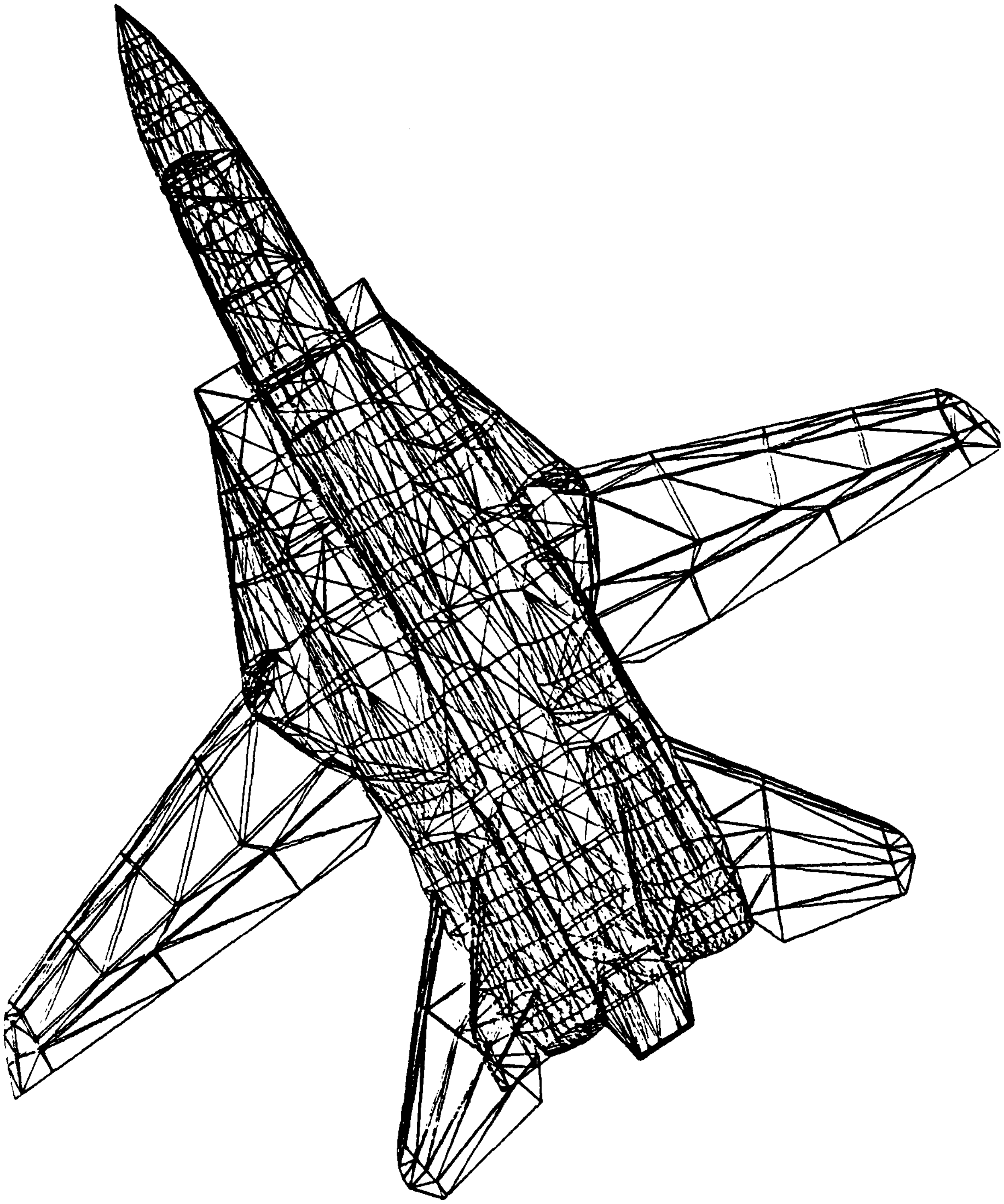


Figure 5. F-14 Survivability/Vulnerability Model

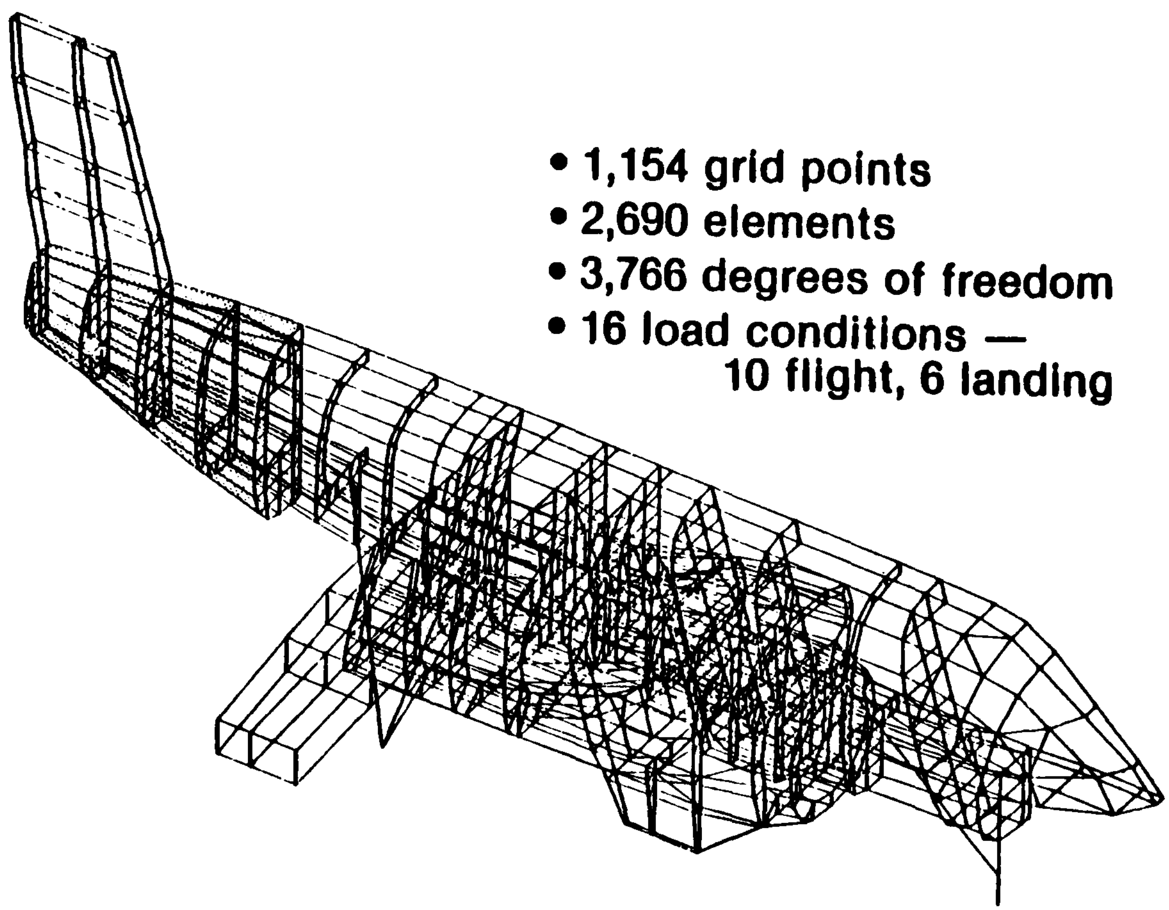


Figure 6. Kevlar Aft Fuselage Section

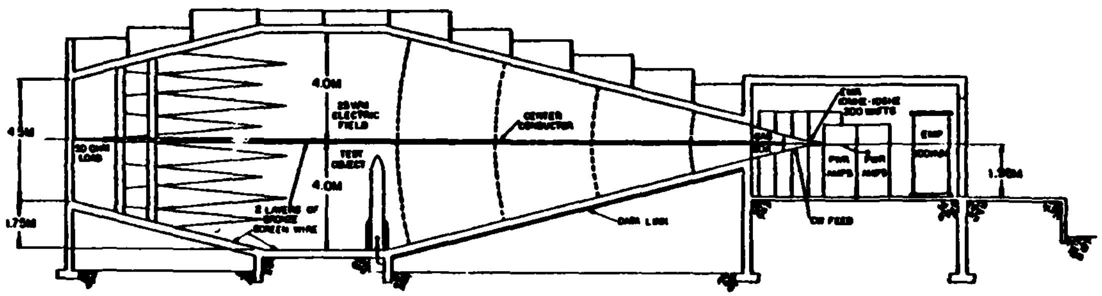


Figure 7. Side View EMES

A28434-U

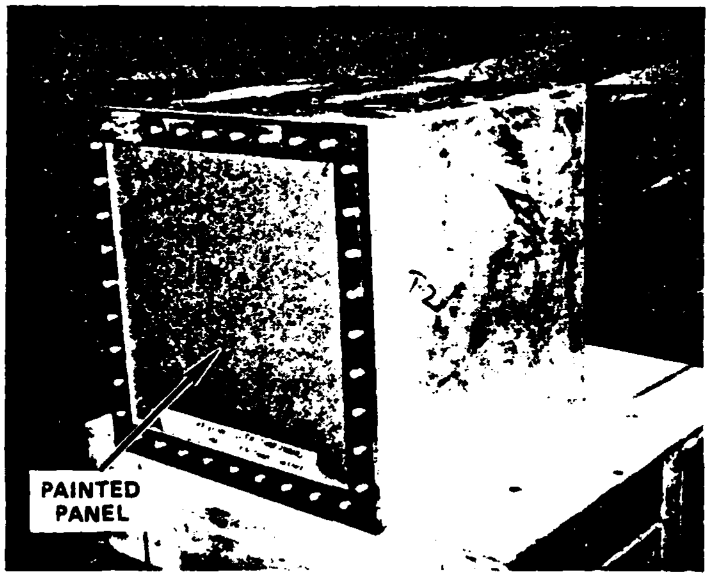


Figure 8. View of Welded Aluminum Box with Kevlar-Thorstrand-Silver Painted Panel Mounted for Test

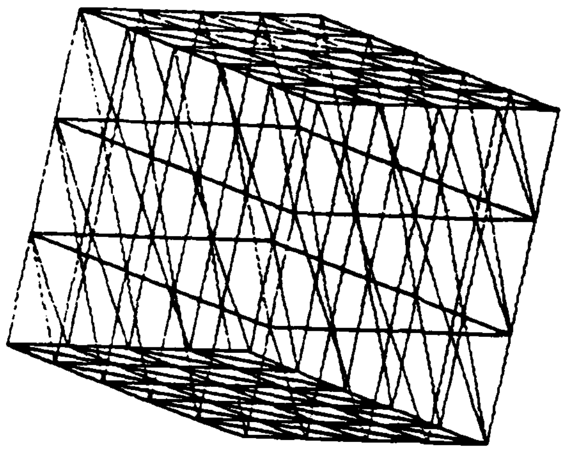


Figure 9. Triangulated Box

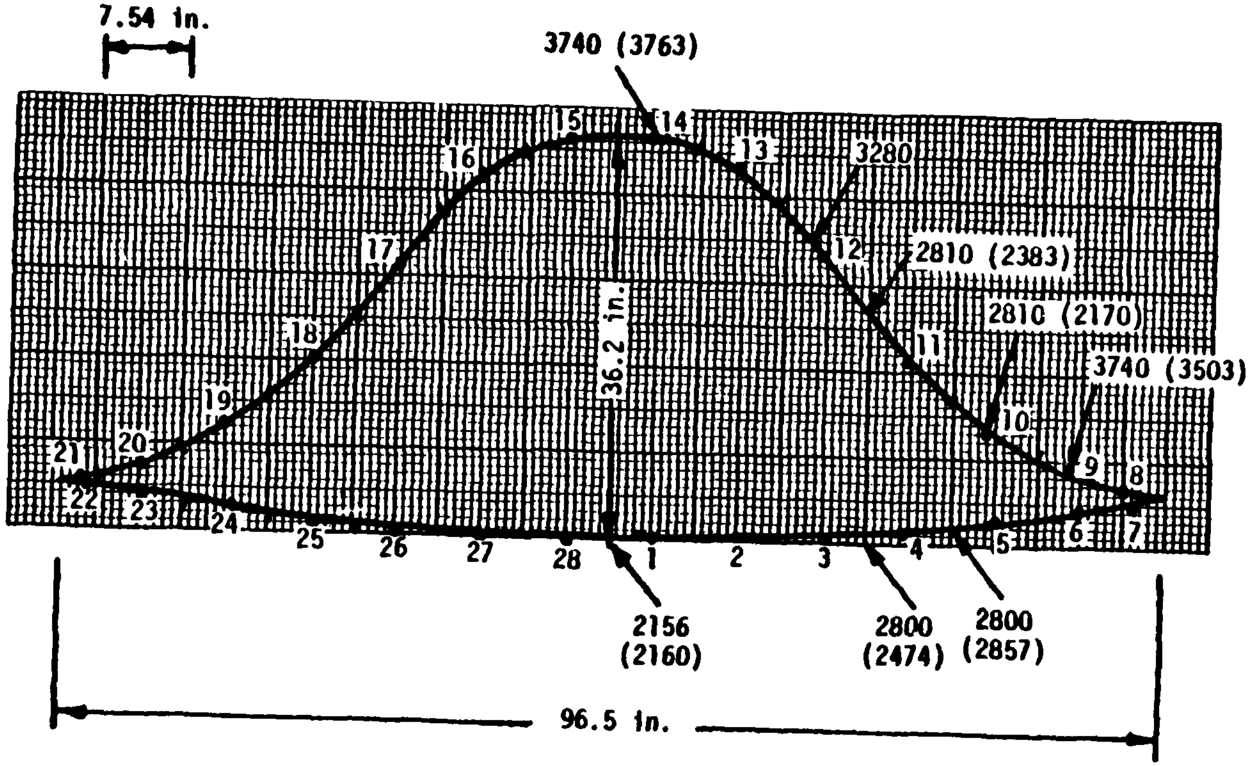


Figure 10. Free-Space Logitudinal Current Distribution on Conducting Cylindrical Contour, I_{total} = 20 kA

- SURFACE CURRENT DENSITY ON MIXED MATERIAL PLATFORM
- TRANSFER IMPEDANCE - $Z_{st}(f,\sigma,d)$
- JOINT ADMITTANCE - $Y_j(f,\sigma,d,w)$
- MAGNETIC AND ELECTRIC SHIELDING $S_{H,E}(Z_{st}F,V/S)$
- MAGNETIC AND ELECTRIC FIELDS
  - EXTERNAL
  - INTERNAL
  - SPATIAL DISTRIBUTION
  - RADAR CROSS SECTION (RCS)
- OPEN-CIRCUIT VOLTAGES AND SHORT-CIRCUIT CURRENT

Figure 11. Output Capabilities

TRIANGULAR PATCH MODELLING OF A THREE-DIMENSIONAL SHELL STRUCTURE COMPOSED OF COMPOSITE MATERIAL PANELS

ASSUMPTIONS

- SURFACE OF BODY MAY BE MODELLED BY A MESH OF TRIANGULAR PATCHES
- EACH PATCH HAS AN EFFECTIVE THICKNESS d WHERE $d \ll \lambda_0$
- EACH PATCH HAS AN EFFECTIVE BULK CONDUCTIVITY σ AND RELATIVE DIELECTRIC CONSTANT ε_r

ADVANTAGES

- ABILITY TO MODEL AN ARBITRARY SURFACE GEOMETRY ACCURATELY
- GIVES EXCELLENT REPRESENTATION OF SURFACE CURRENTS AND CHARGE DENSITIES WHICH ARE NEEDED FOR SMALL APERTURE AND JOINT COUPLING FORMULATIONS
- BETTER INTERIOR FIELD COMPUTATIONS THAN ACHIEVED WITH WIRE-GRID OR OTHER NON-SURFACE PATCH TECHNIQUES

DISADVANTAGES

- MATRIX SIZE INCREASES VERY RAPIDLY WITH BODY ELECTRICAL SIZE AND/OR GEOMETRICAL COMPLEXITY

Figure 12. Output Capabilities

- F-14; MIXED ALUMINUM AND GRAPHITE/EPOXY
- F-16
- BOX - KEVLAR, KEVLAR WITH PROTECTIVE COATING
- V/STOL - KEVLAR WITH THORSTRAND

Figure 13. Cases Considered

- F-16 MOCKUP; GRAPHITE/EPOXY FORWARD FUSELAGE
- HAWKER
- BOX
- V/STOL AFT FUSELAGE
- MX CANNISTER

Figure 14. Cases Measured

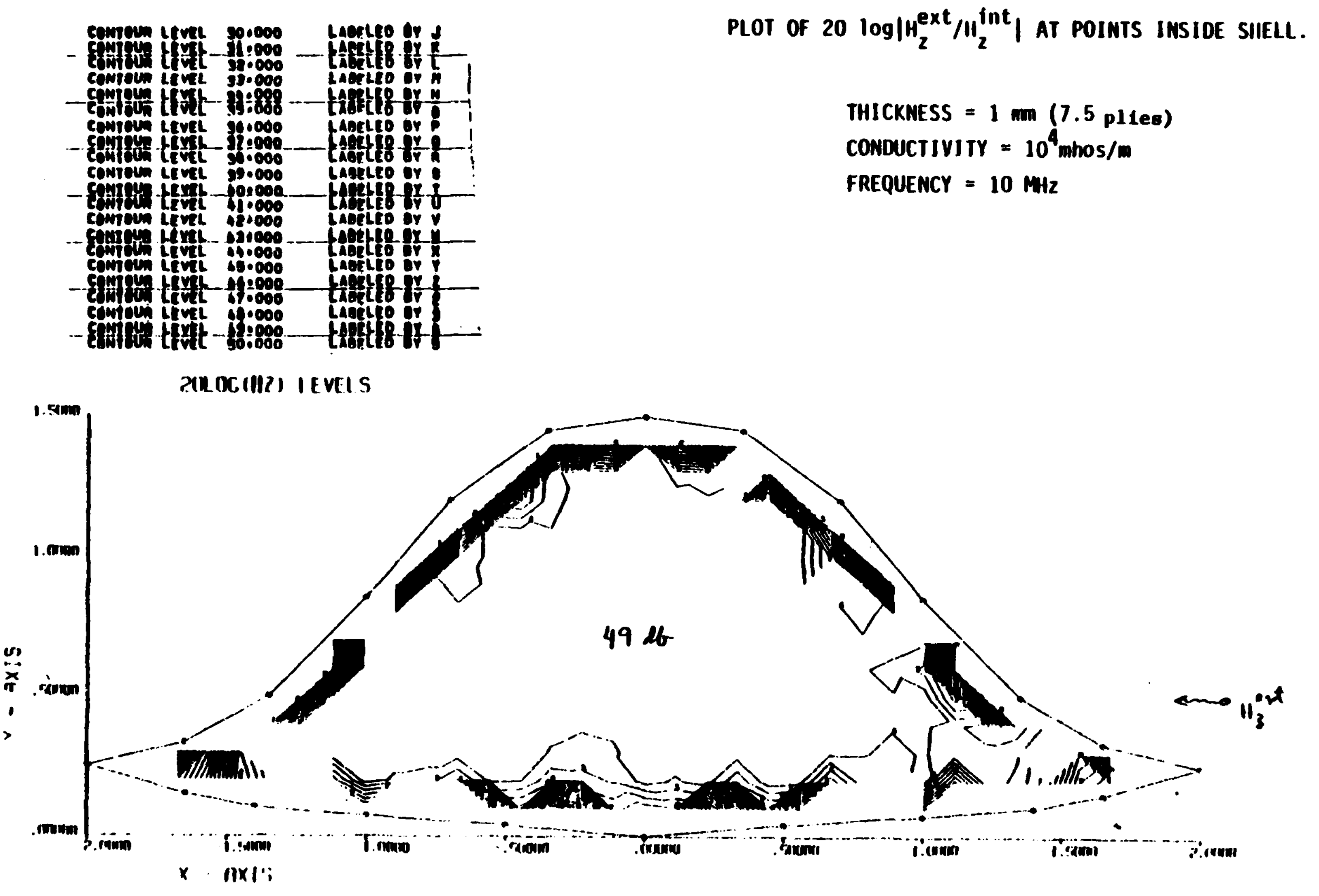


Figure 15. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage

PLOT OF 20 $\log|E_z^{ext}/E_z^{int}|$ AT POINTS

INSIDE SHELL.

THICKNESS = 1 mm (7.5 plies)

CONDUCTIVITY = 10^4 mhos/m except where noted

FREQUENCY = 0.1 MHz

CONTOUR PLOT • 20LOG(EZ) LEVELS

CONTOUR LEVEL	32.500	LABELED BY A
CONTOUR LEVEL	33.000	LABELED BY B
CONTOUR LEVEL	33.500	LABELED BY C
CONTOUR LEVEL	34.000	LABELED BY D
CONTOUR LEVEL	34.500	LABELED BY E
CONTOUR LEVEL	35.000	LABELED BY F
CONTOUR LEVEL	35.500	LABELED BY G
CONTOUR LEVEL	36.000	LABELED BY H
CONTOUR LEVEL	36.500	LABELED BY I
CONTOUR LEVEL	37.000	LABELED BY J
CONTOUR LEVEL	37.500	LABELED BY K
CONTOUR LEVEL	38.000	LABELED BY L
CONTOUR LEVEL	38.500	LABELED BY M
CONTOUR LEVEL	39.000	LABELED BY N
CONTOUR LEVEL	39.500	LABELED BY O
CONTOUR LEVEL	40.000	LABELED BY P
CONTOUR LEVEL	40.500	LABELED BY Q

20LOG(EZ) LEVELS

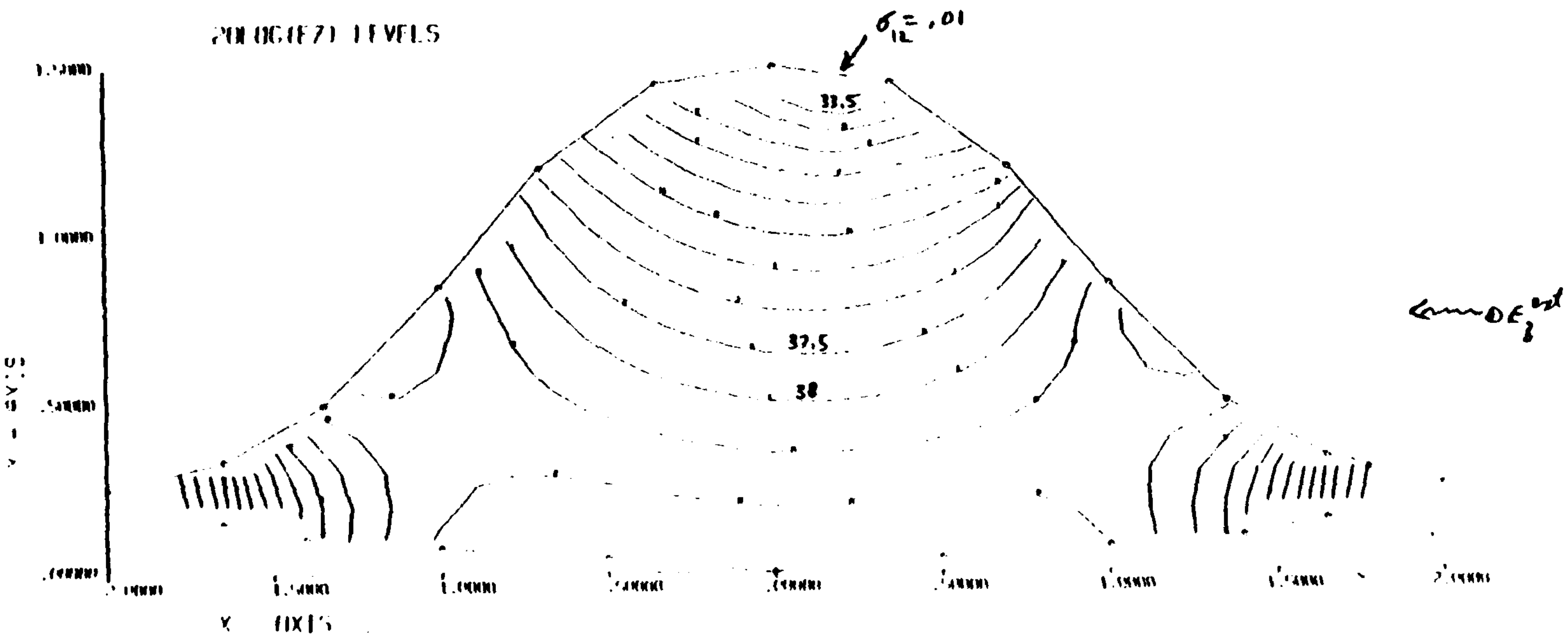


Figure 16. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage with the Effect of a Window

CONTOUR PLOT - 20LOG(EZ) LEVELS

CONTOUR LEVEL 37.000 LABELED BY A
CONTOUR LEVEL 39.000 LABELED BY B
CONTOUR LEVEL 41.000 LABELED BY C
CONTOUR LEVEL 43.000 LABELED BY D
CONTOUR LEVEL 45.000 LABELED BY E
CONTOUR LEVEL 47.000 LABELED BY F
CONTOUR LEVEL 49.000 LABELED BY G
CONTOUR LEVEL 51.000 LABELED BY H
CONTOUR LEVEL 53.000 LABELED BY I
CONTOUR LEVEL 55.000 LABELED BY J
CONTOUR LEVEL 57.000 LABELED BY K
CONTOUR LEVEL 59.000 LABELED BY L
CONTOUR LEVEL 61.000 LABELED BY M
CONTOUR LEVEL 63.000 LABELED BY N
CONTOUR LEVEL 65.000 LABELED BY O
CONTOUR LEVEL 67.000 LABELED BY P
CONTOUR LEVEL 69.000 LABELED BY Q
CONTOUR LEVEL 71.000 LABELED BY R
CONTOUR LEVEL 73.000 LABELED BY S
CONTOUR LEVEL 75.000 LABELED BY T
CONTOUR LEVEL 77.000 LABELED BY U
CONTOUR LEVEL 79.000 LABELED BY V

PLOT OF $20 \log|E_z^{ext}/E_z^{int}|$ AT POINTS

INSIDE SHELL.

THICKNESS = 1 mm (7.5 plies)

CONDUCTIVITY = 10^4 mhos/m except where noted

FREQUENCY = 10 MHz

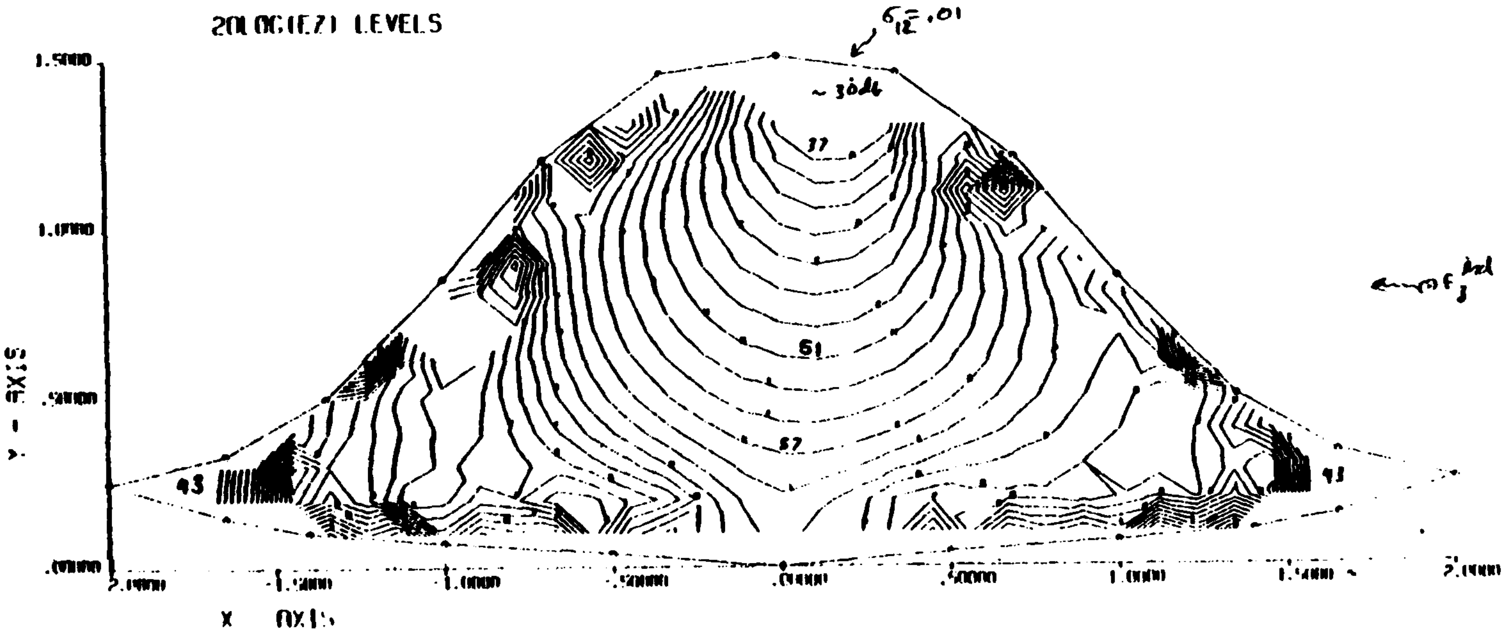


Figure 17. Electric Shielding Inside a Two-Dimensional Graphite/Epoxy F-16 Forward Fuselage with the Effect of a Window

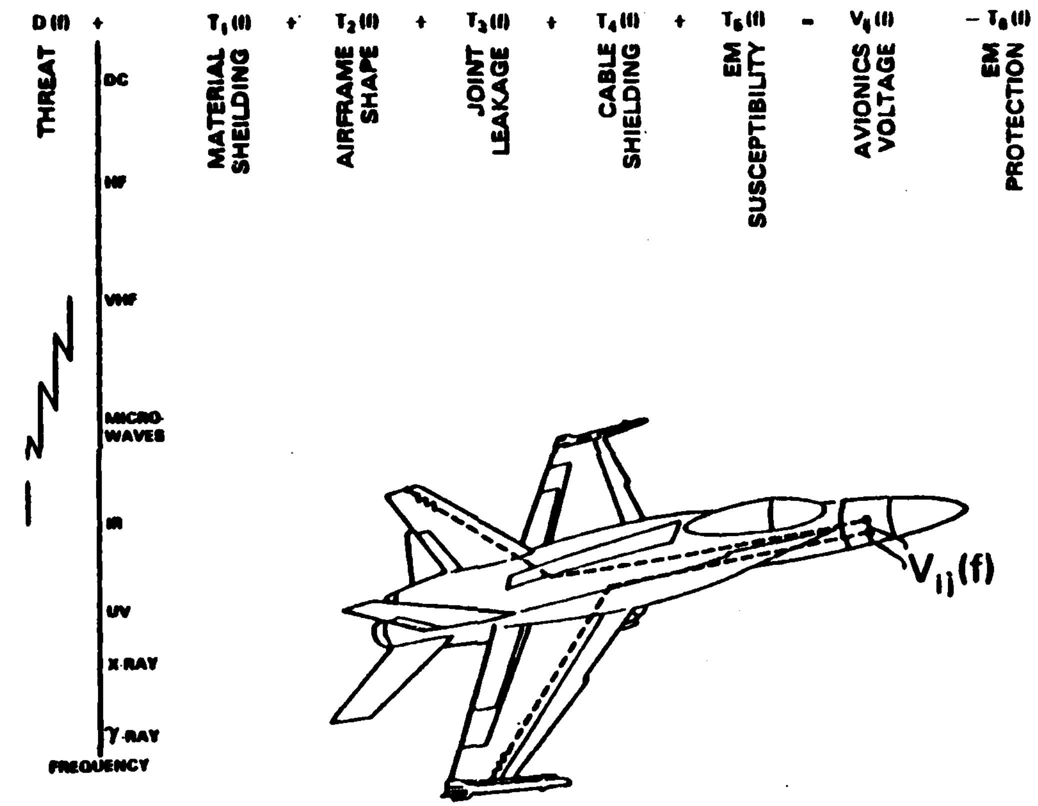


Figure 18. Electromagnetic System Parameters

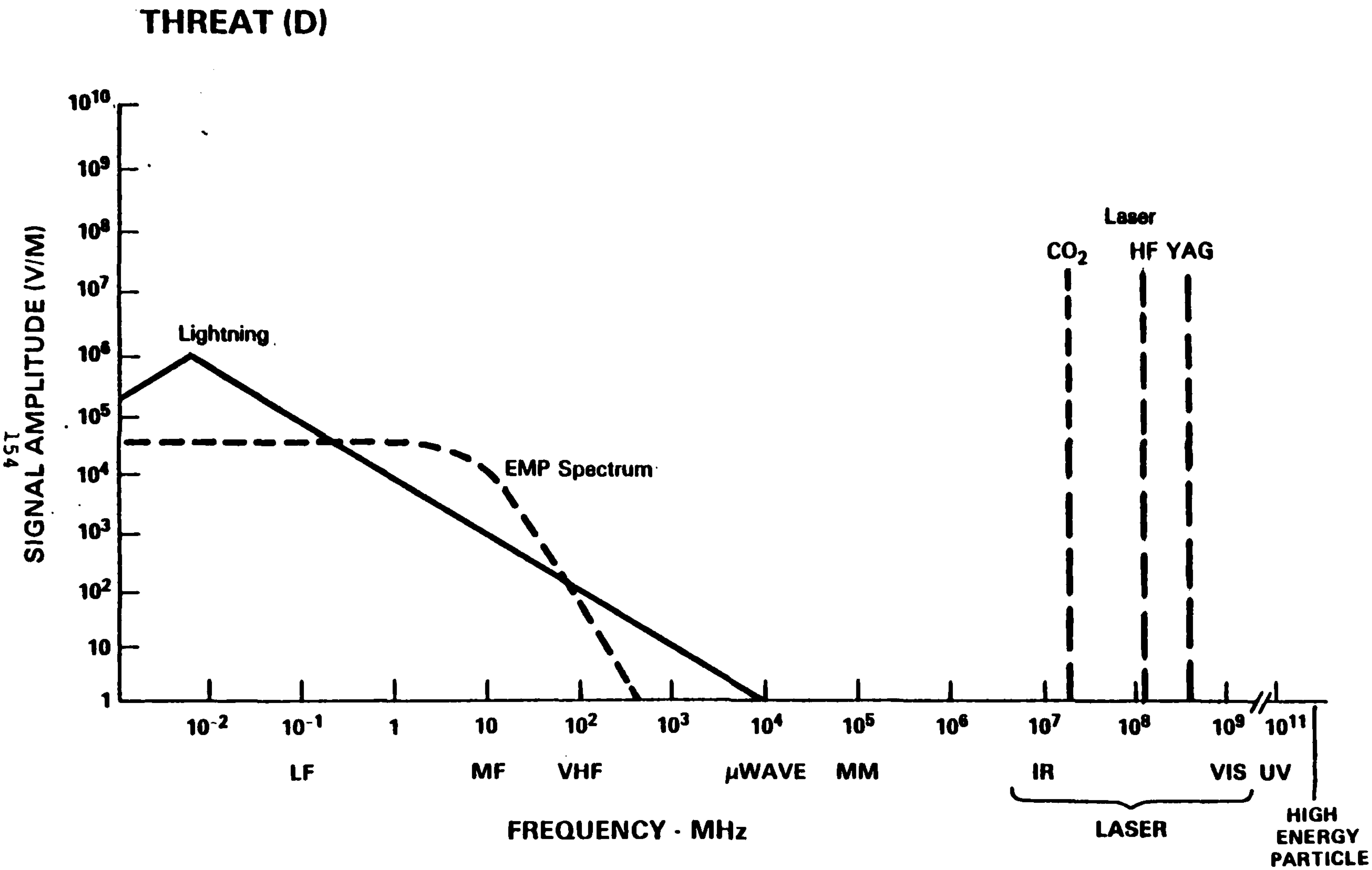


Figure 19. Threat Spectrum

MATERIAL THICKNESS CORRESPONDS TO 8 PLY COMPOSITE
MATERIAL AT 0.00525 IN/PLY

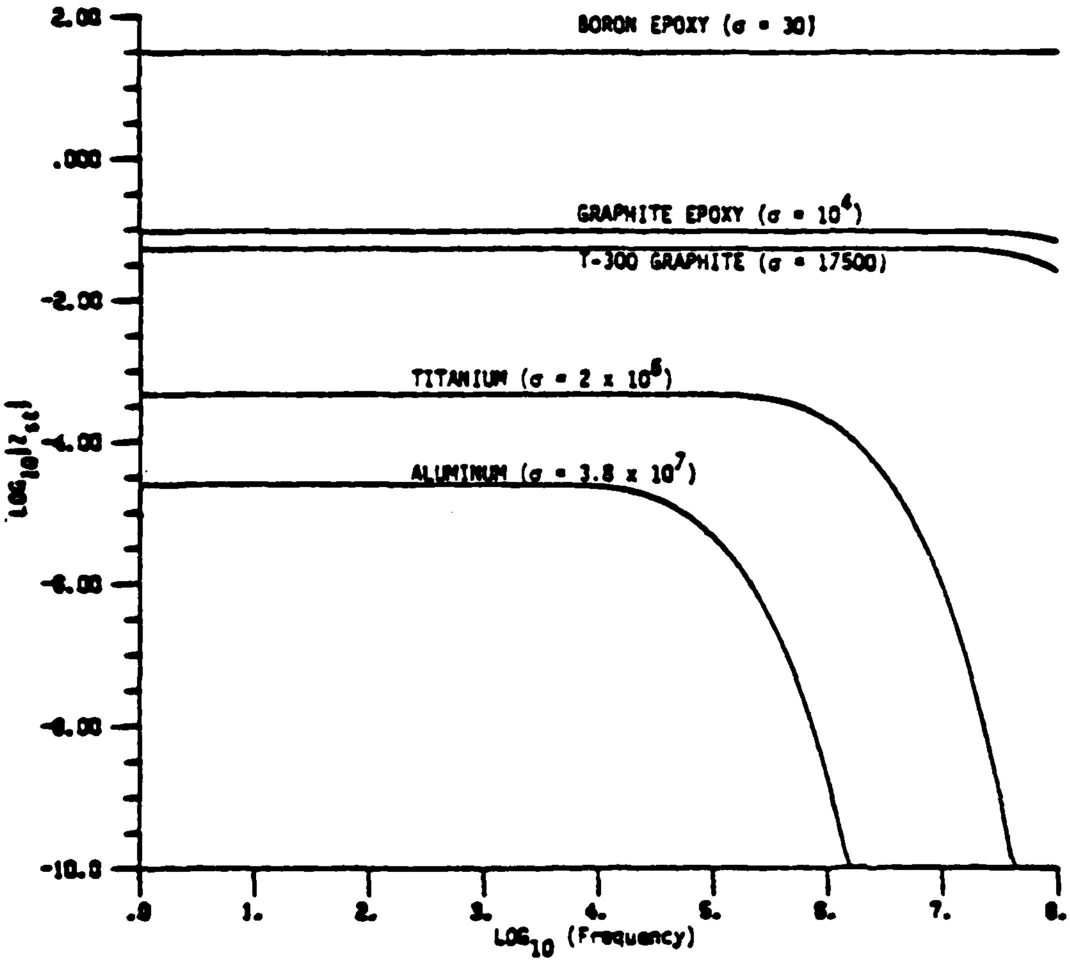


Figure 20. Surface Transfer Impedances for Different Materials

EM PROTECTION OF METALS AND COMPOSITES (T_e)

Transfer Impedance Shielding of Structural Materials and Protective Electromagnetic Coatings

(Valid for Frequencies Below 10^5 Hz)

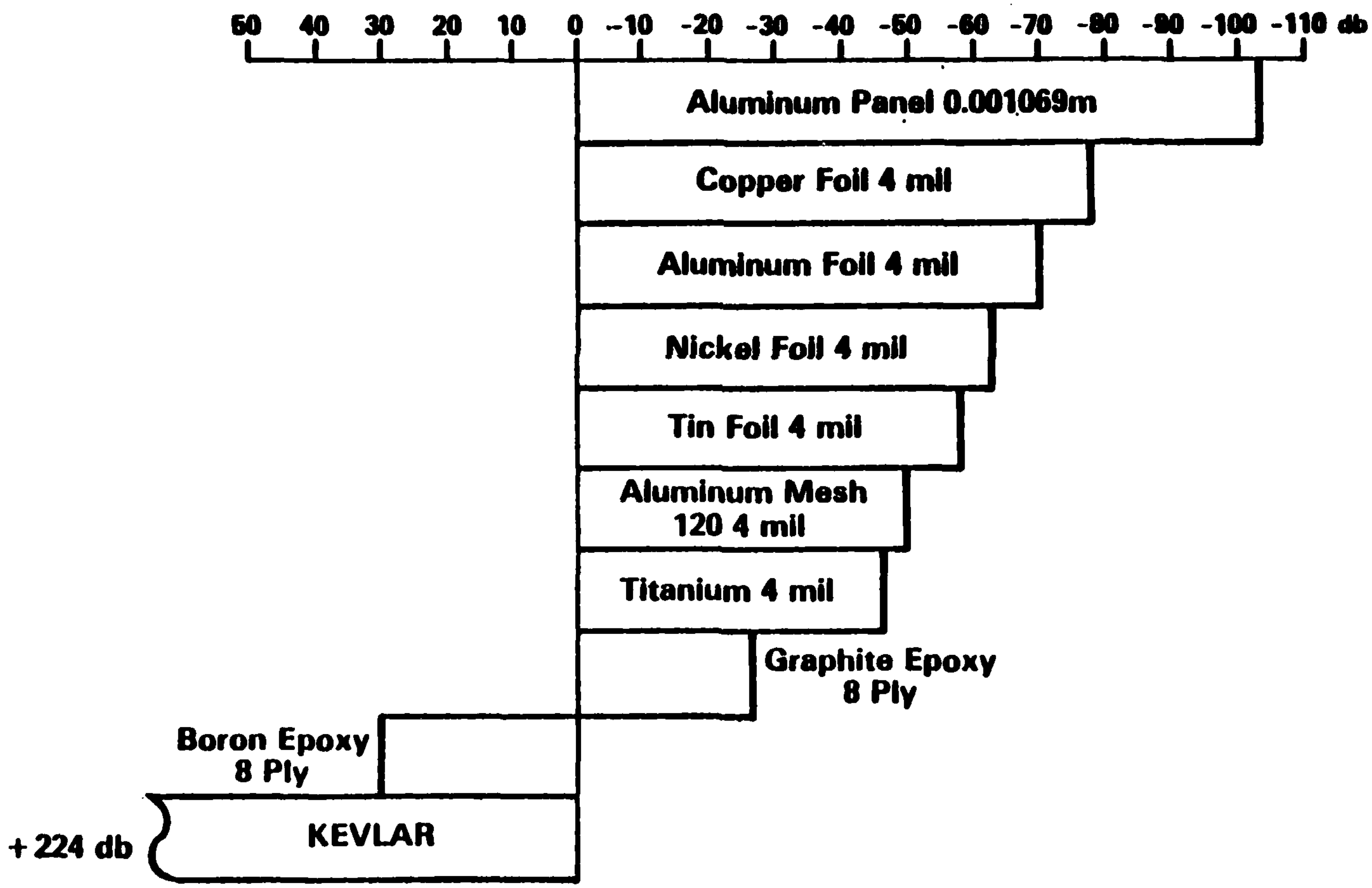


Figure 21. Transfer Impedance Shielding of Structural Materials and Protective Electromagnetic Coatings

AIRFRAME SHAPE (T_2)

The Shape of an Aircraft Influences EM Coupling

MAGNETIC SHIELDING EFFECTIVENESS for a Uniform Incident Magnetic Field. SHIELD CONDUCTIVITY = 10^4 Ω/m. Shield Thickness = 0.00107 m (CORRESPONDING TO 8 PLY Composite Material at 0.00525 In/Ply)

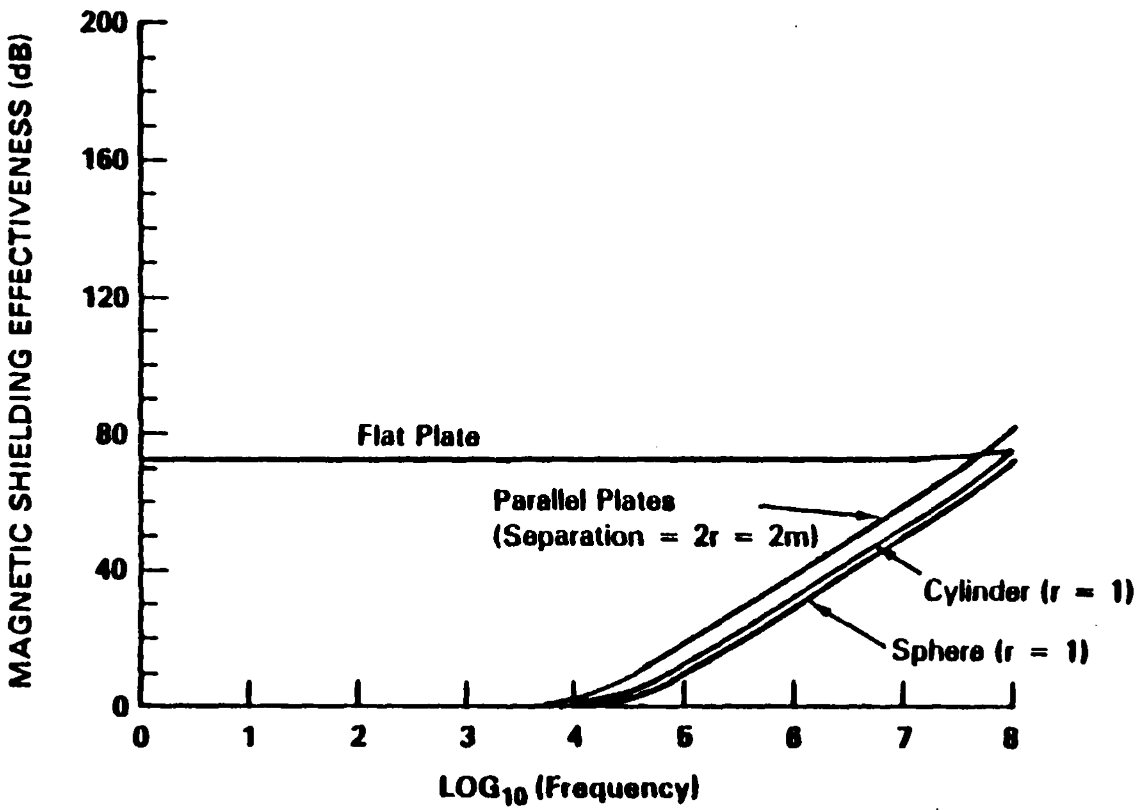


Figure 22. Magnetic Shielding Effectiveness for Various Shapes

AIRFRAME SHAPE (T_2)

MAGNETIC SHIELDING EFFECTIVENESS of an Enclosure Under a Uniform Magnetic Field as a Function of Volume-To-Surface Ratio. SHIELD CONDUCTIVITY = 17500 Ω/m. Shield Thickness = 0.00107 m (CORRESPONDING TO 8 PLY Composite Material at 0.00525 In/Ply)

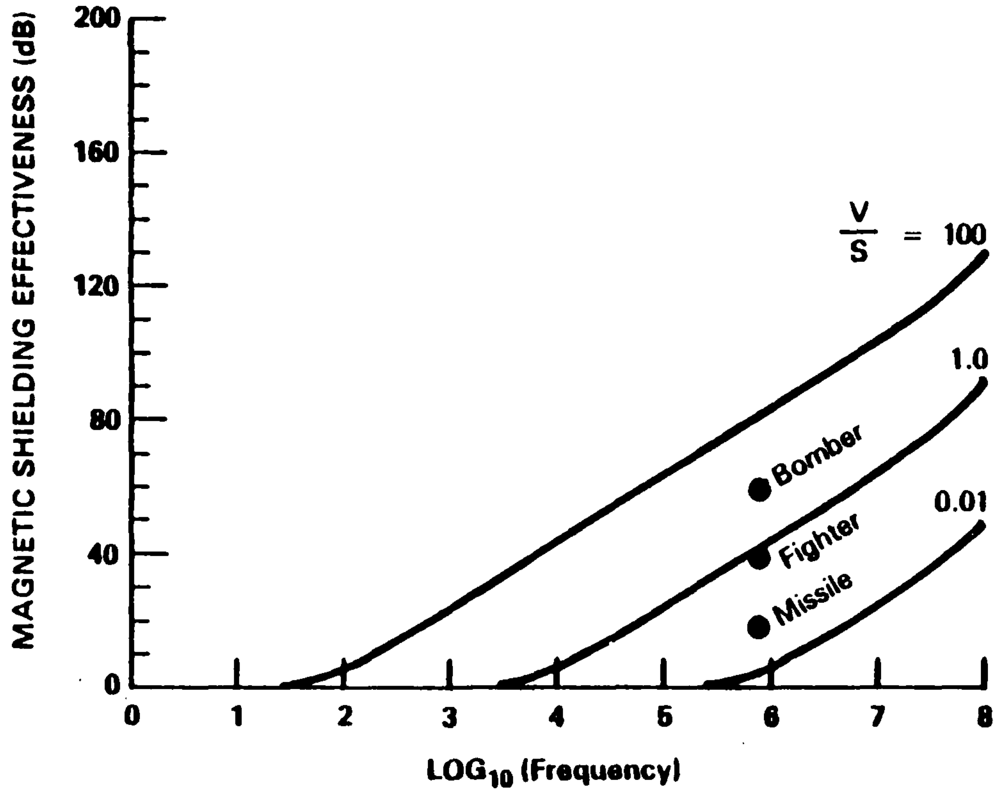


Figure 23. Magnetic Shielding Effectiveness for Various Shapes

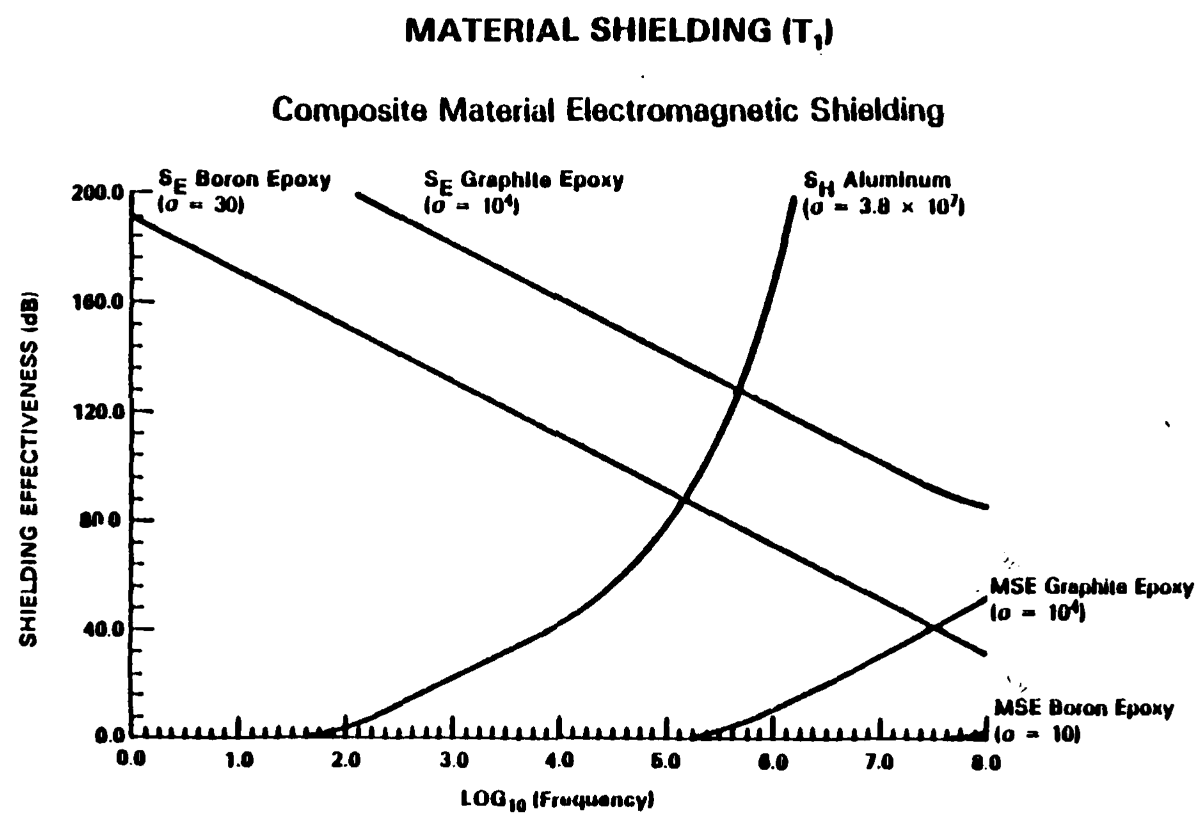


Figure 24. Magnetic S_H and Electric S_H Shielding Effectiveness for Various Materials

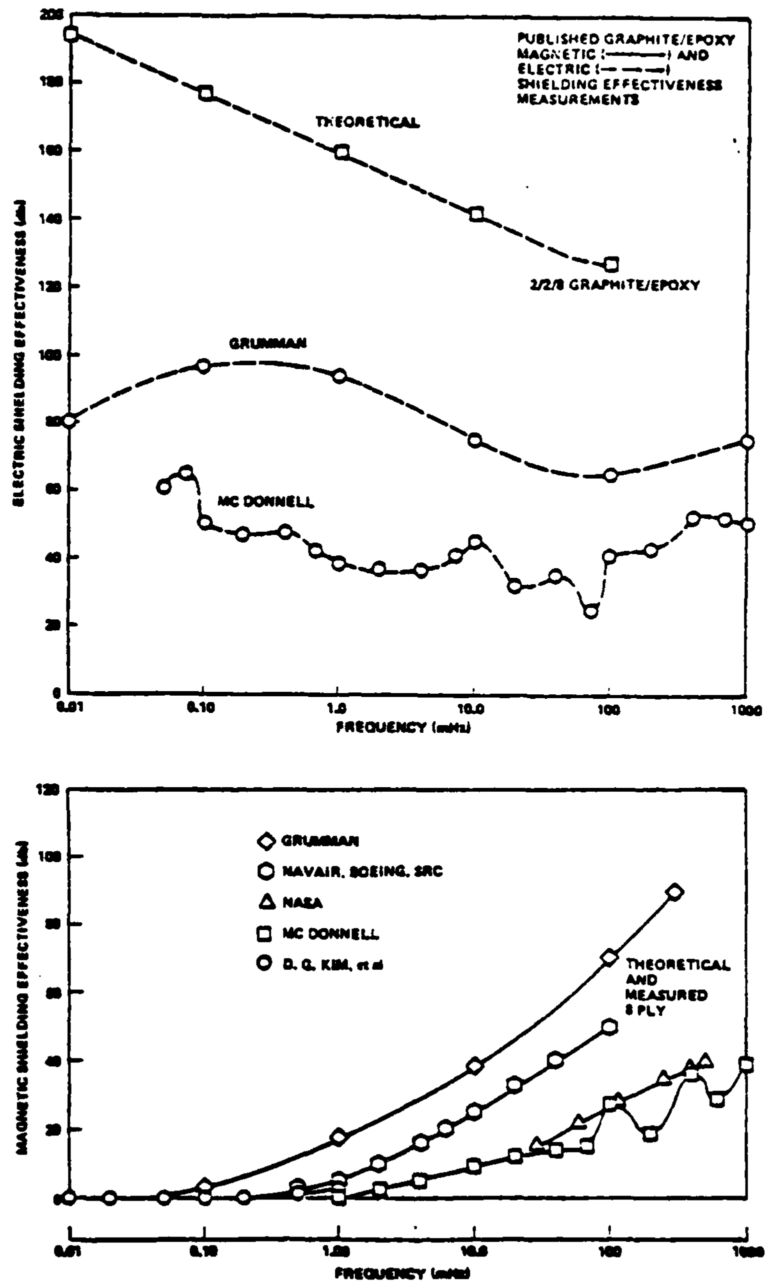


Figure 25. Published Graphite/Epoxy Magnetic and Electric Shielding Effectiveness

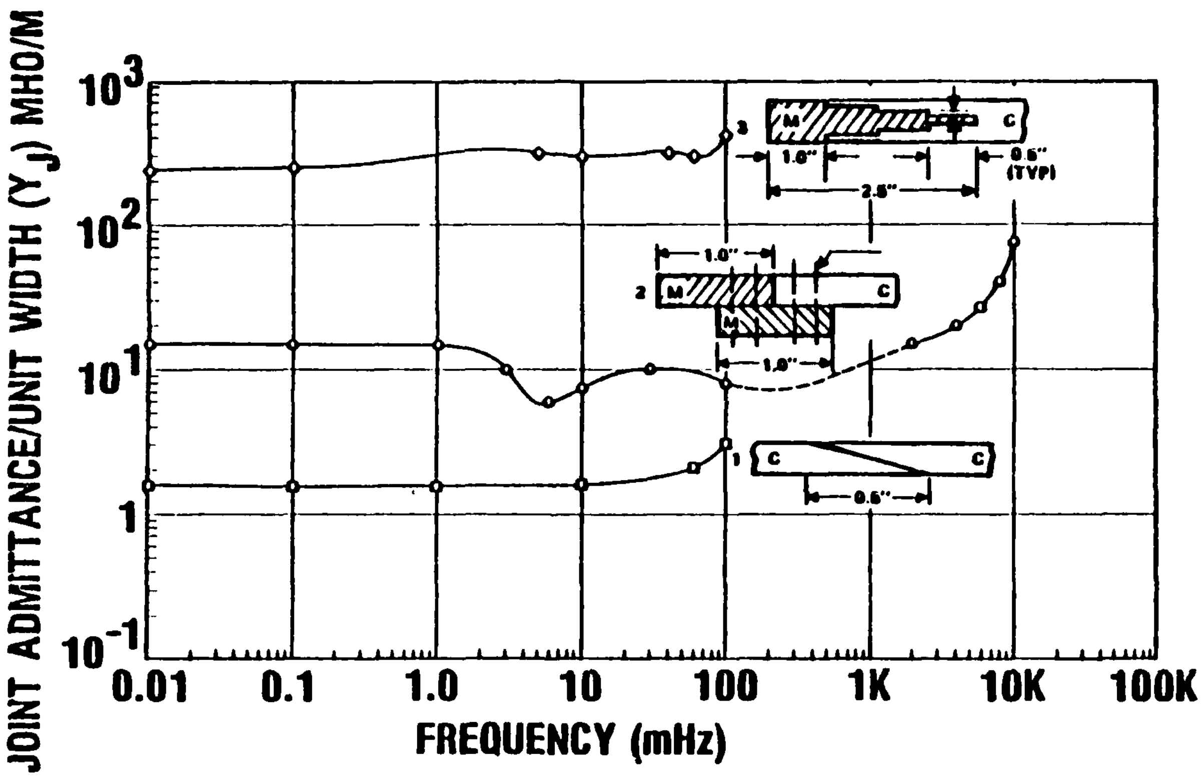


Figure 26. Joint Admittance/Unit Width as a Function of Frequency

TECHNOLOGY TRENDS

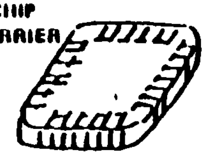
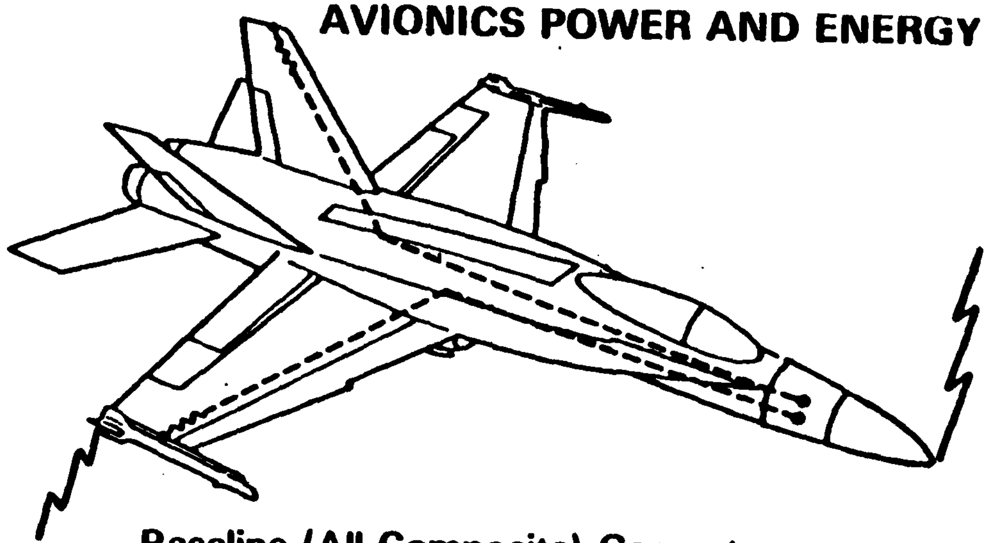
TUBES	DISCRETE TRANSISTORS	INTEGRATED CIRCUITS (IC)	LARGE SCALE INTEGRATED CIRCUITS (LSI)	VERY LARGE SCALE INTEGRATED CIRCUITS (VLSI)
	 TO-5	FLAT PACK 	 DIP	CHIP CARRIER 
250V 1 WATT/DEVICE	12V–24V 10^{-1}–10^{-2} WATTS/DEVICE	5V–12V 10^{-2}–10^{-3} WATTS/TRANS	5V–7V 10^{-3}–10^{-4} WATTS/TRANS	1.5V–3V 10^{-6}–10^{-8} WATTS/TRANS
GLASS/ METAL/ CERAMIC	METAL/ CERAMIC	METAL/ CERAMIC/ EPOXY	METAL/ CERAMIC/ EPOXY	CERAMIC/ EPOXY
F-9	F-4	F-14	F-18	VSTOL
ALUMINUM	ALUMINUM	ALUMINUM/TITAN	GRAPHITE-EPOXY ALUMINUM	GRAPHITE-EPOXY ?
PRE-1950's	1950's	1960's	1970's	1980's

Figure 27. Aerospace Technology Trends

AVIONICS POWER AND ENERGY



Baseline (All Composite) Geometry

Peak Power and Maximum Energy

Direct Strike		V_{ij} (Volts)	I_{ij} (Amps)	P_{ij}^{peak} (Kilowatts)	E_{ij} (Joules)
Nose/Tail Wire	(Nose/Tail Attachment)	32,000	1,100	3,520	1036.2 J
	(Nearby Strike)	250	8.2	2	0.069 J
Nose/Wing Tip Wire	(Nose/Tail Attachment)	6,500	220	1,430	42.06 J
	(Nose/Wing Tip Attachment)	17,000	550	9,350	276.0 J

Figure 28. Voltage, Current, Power, and Energies Caused by LEMP and NEMP External Fields on a Meter Long Power Line in an Aluminum or Graphite/Epoxy Fuselage

EM PROTECTION (T_6)

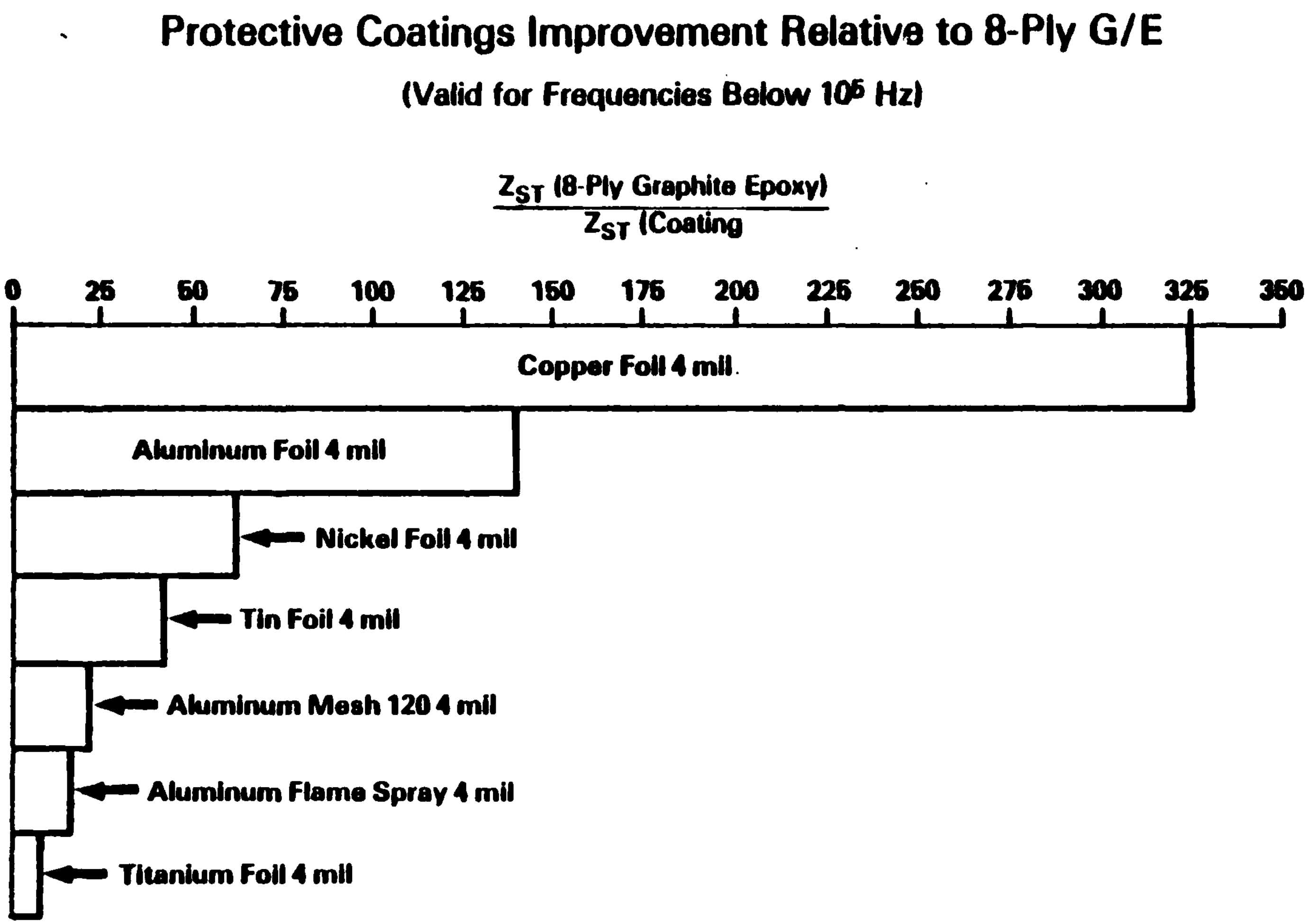


Figure 29. Improvement Protective Coatings Provided Relative to 8-Ply Graphite/Epoxy

EM PROTECTION WEIGHT PENALTIES (T_a)

Forward Fuselage AV-8B (Area - 100 Ft^2) Weight Penalty (Pounds) Imposed by Electromagnetic Protective Coatings

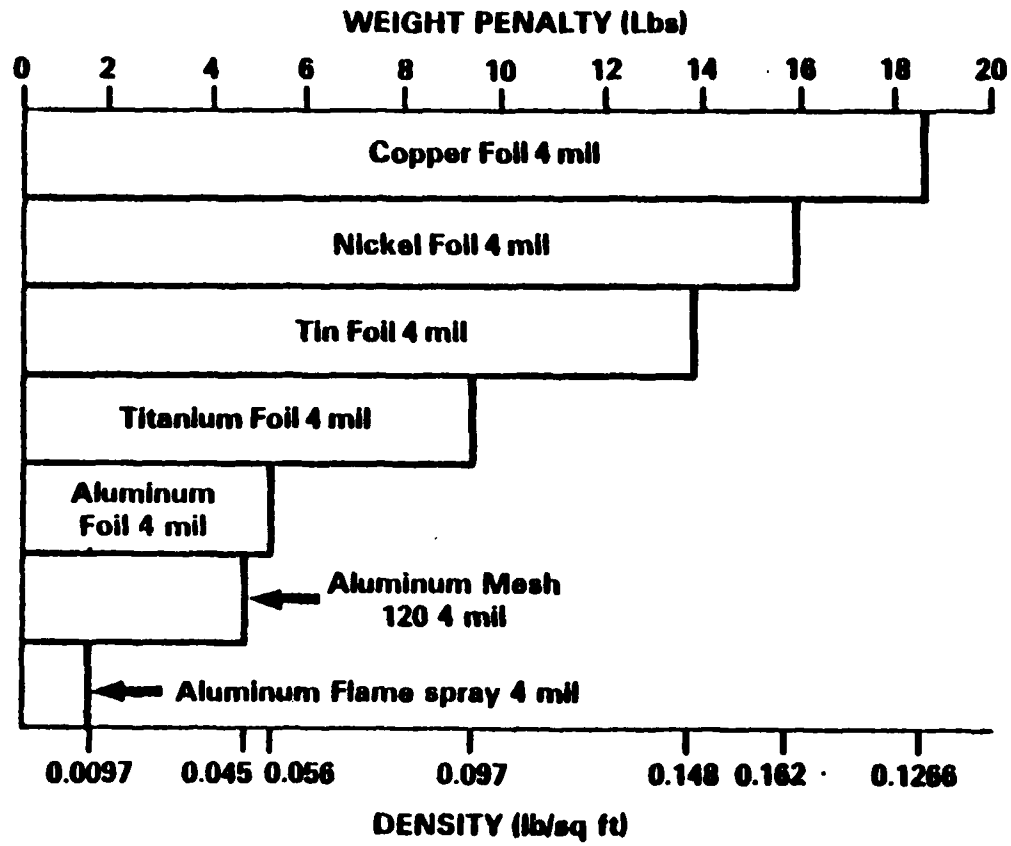


Figure 30. Weight Penalty Imposed by Protective Coatings

EM PROTECTION (T_6)

Weight Shielding Figure of Merit

(Protection Beyond 8-Ply G/E Provided by the Weight of 1 Square Foot of Protective Coating)

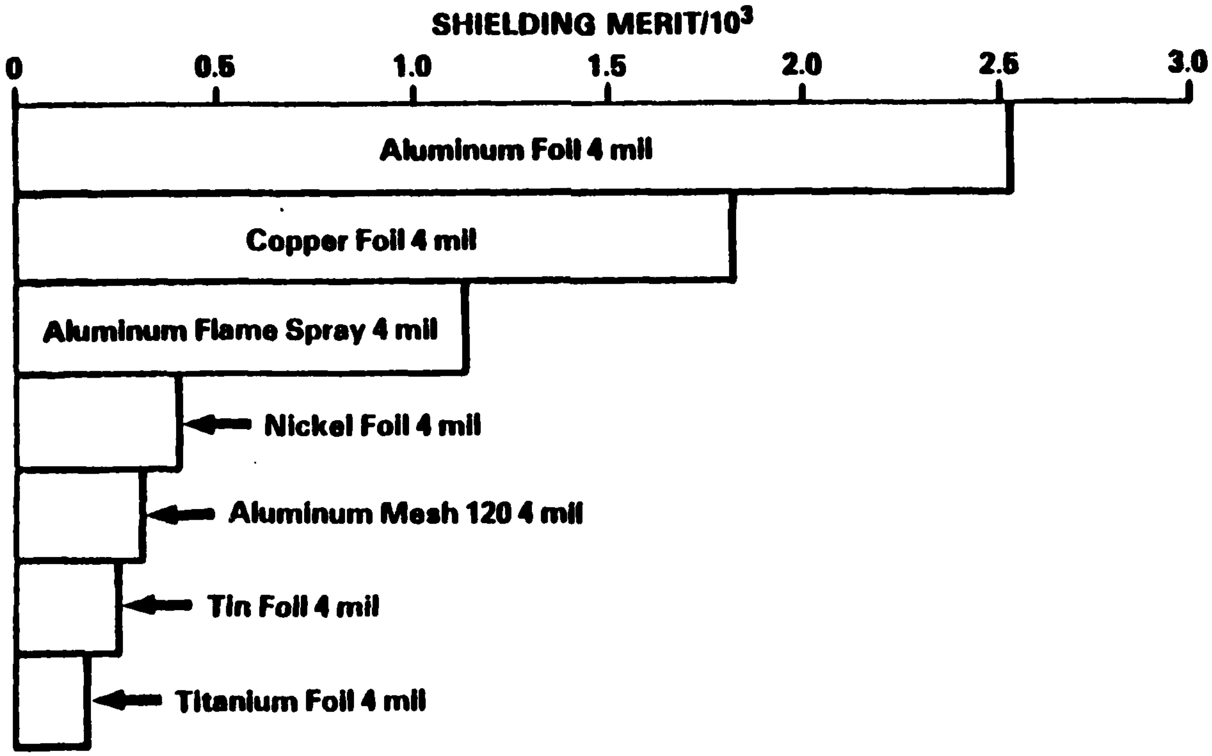


Figure 31. Weight/Shielding Figure of Merit of EM Protective Coatings

COMPUTER-AIDED AIRCRAFT CONCEPTUAL DESIGN CAPABILITY IN THE NAVAL AIR SYSTEMS COMMAND AND ITS FUTURE DEVELOPMENT

Rudi F. Saenger
Naval Air Systems Command
Washington, D.C.

COMPUTER-AIDED AIRCRAFT CONCEPTUAL DESIGN CAPABILITY IN THE NAVAL AIR SYSTEMS COMMAND AND ITS FUTURE DEVELOPMENT

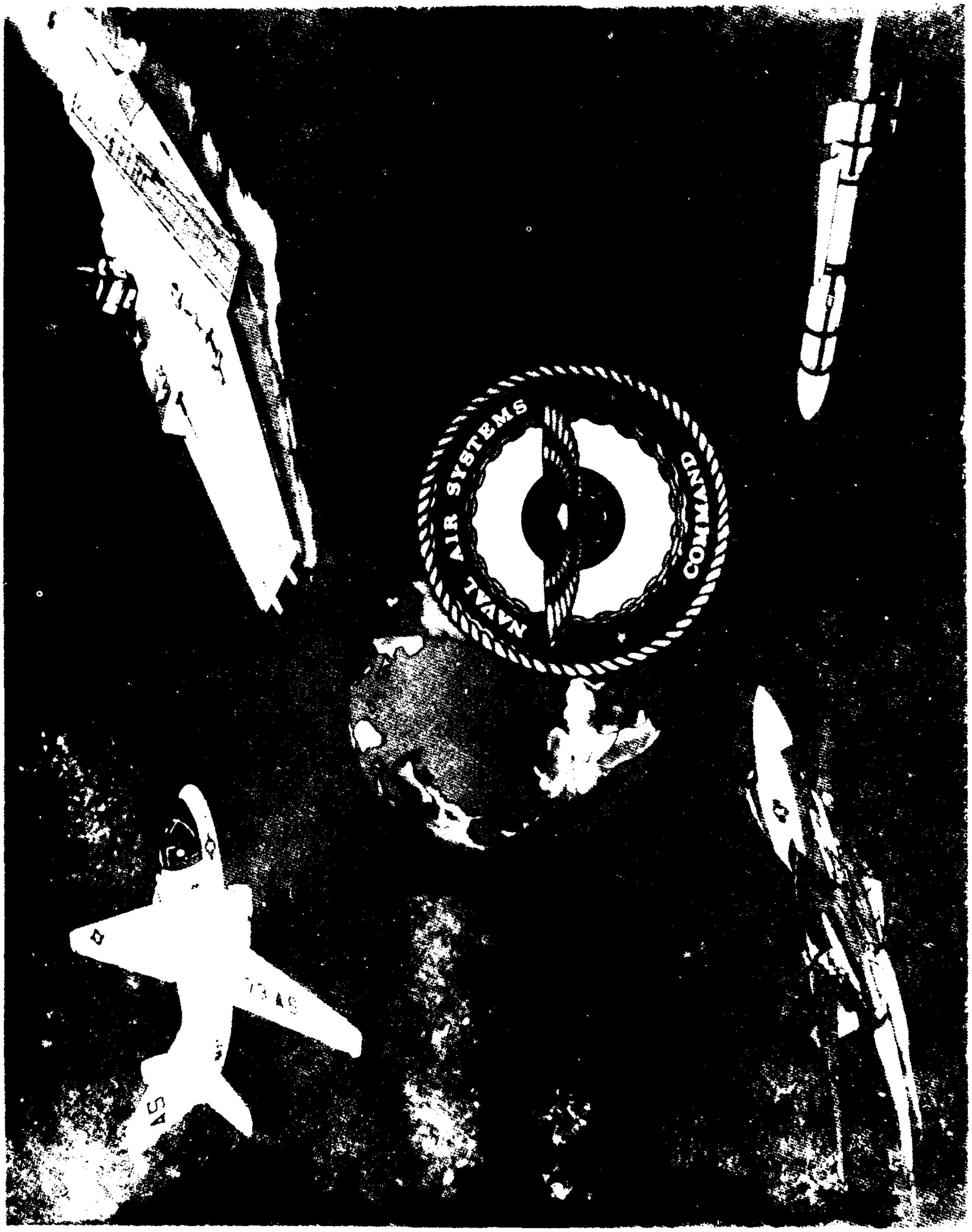
Rudi F. Saenger
Naval Air Systems Command
Washington, D.C.

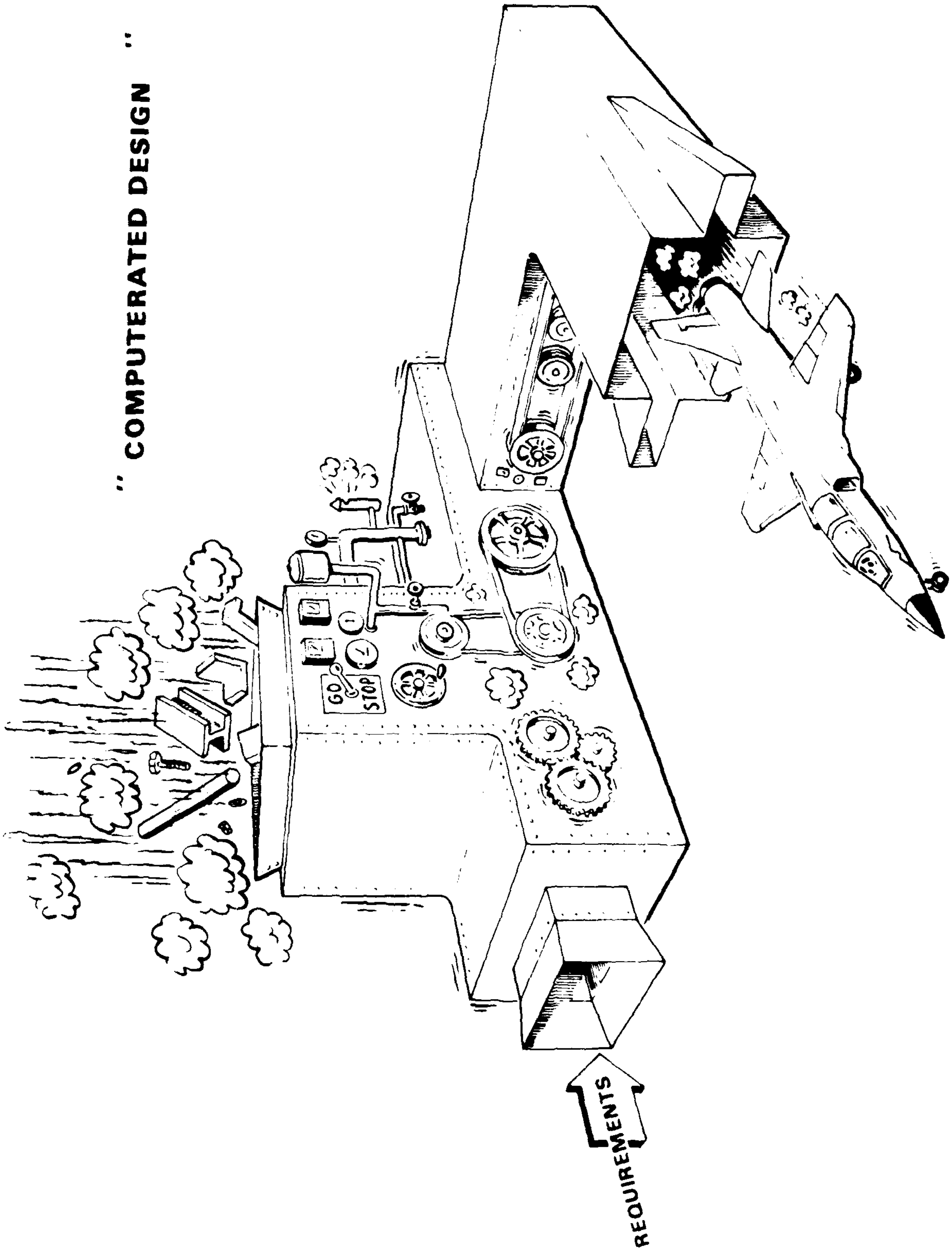
Computer-aided aircraft conceptual design, more and more, is becoming a necessity for both government and industry alike. Some of the reasons for this are dramatically expanding technology, competition from other countries, greatly increased workload, shortened response time, reduced numbers of personnel, and present inefficient use of critical skills. Given the enormously increased and increasing cost of aircraft, and the tendency to extend service life years beyond initial plans, it has become vital to optimize every possible aspect of aircraft conceptual design. Industry is substantially ahead of government in implementing computer technology. Unless strong steps are taken, NAVAIR will soon be:

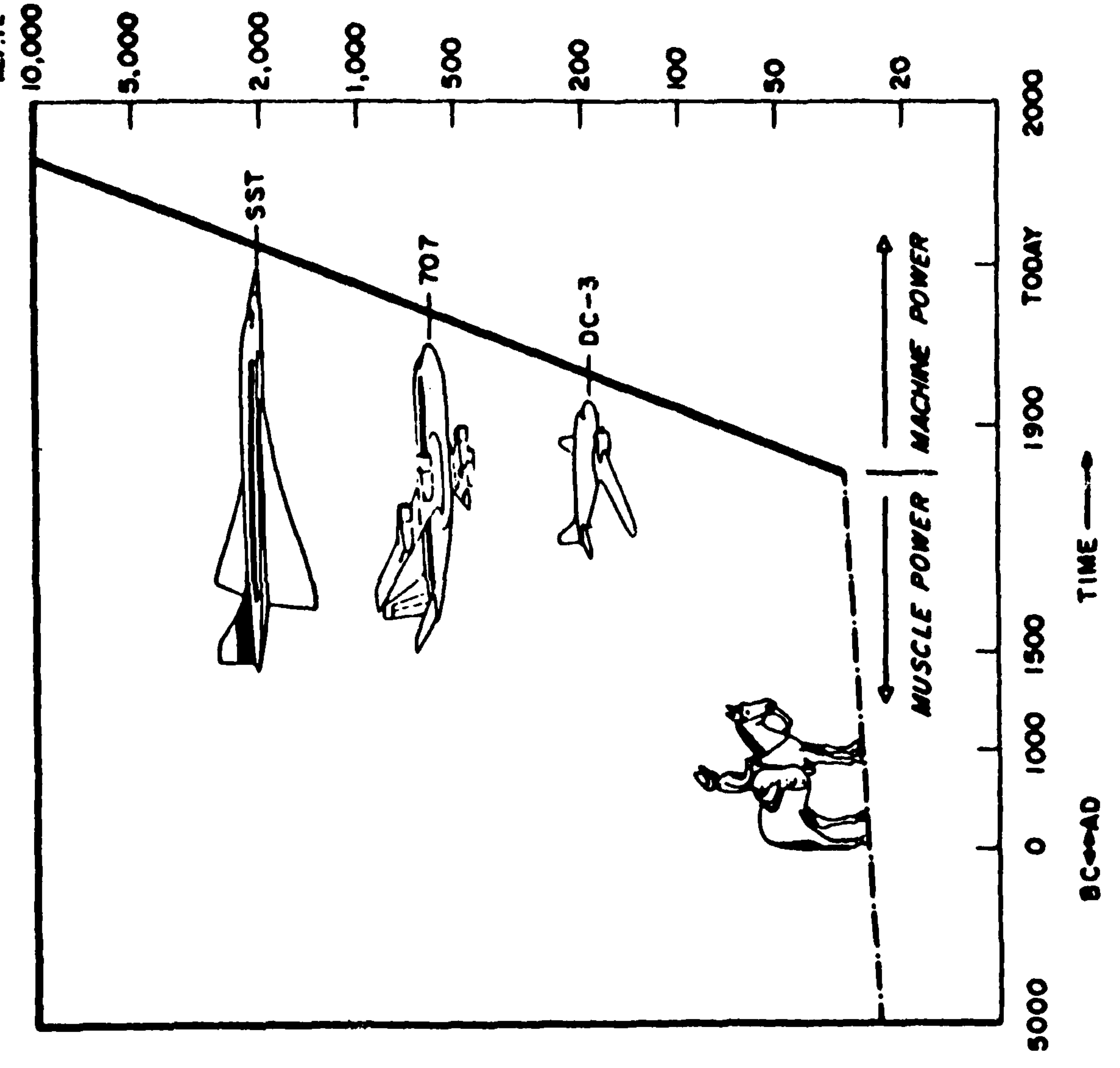
- Unable to pass judgment on future designs
- Losing ground relative to industry in technology development
- Unable to respond in a timely fashion to work requested by higher authority.

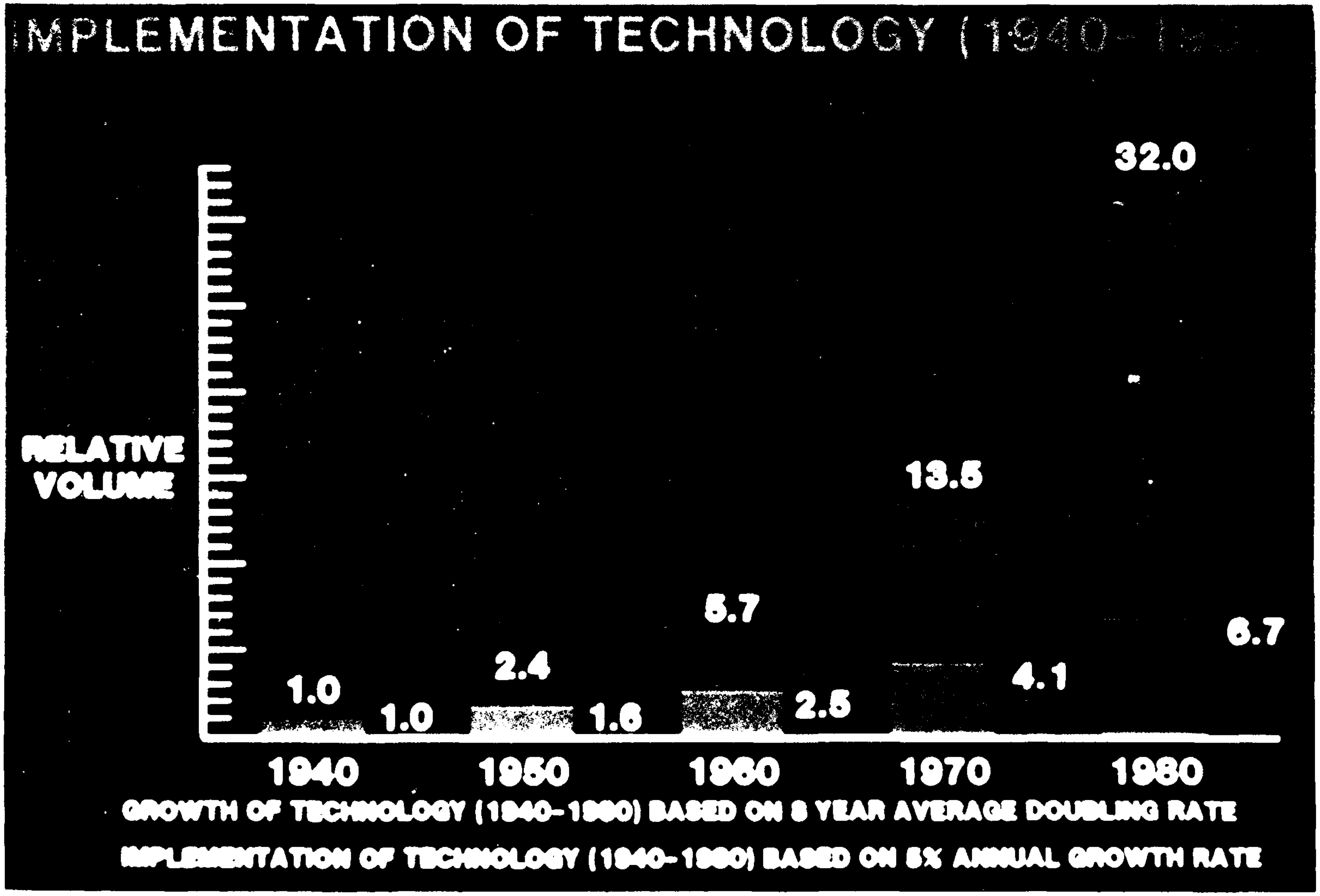
NAVAIR has established the NAVAIR Integrated Computer-Aided Design (NICAD) program to meet this challenge. The program concept calls for computer-aided design capability for aircraft, missiles and helicopters. The first step in building the NICAD system will be defining and acquiring a NAVAIR Aircraft Synthesis Program (NASP). NASP will be based on existing industry and government programs. It will have an extensive compatible format data base with individual modules for dealing with specialized requirements, such as propulsion, aerodynamics, reliability, and survivability to name just a few. The system will be constructed to allow specialists representing the various disciplines to optimize the aircraft through trade studies for each of the critical parameters. The output of such a computer aided design synthesis would be a series of optimum or near optimum design choices from which a final design would be chosen--custom tailored, so to speak--for the operational requirement.

Also planned is a computer graphics type conference room designed to allow presentation of design study results to decision officials. As planned, this facility would allow fielding of questions requiring further computer operation while meetings are in progress. This will expedite decisionmaking while tightly scheduled executives are assembled and eliminate scheduling delays for future meetings or laborious drop cycles.

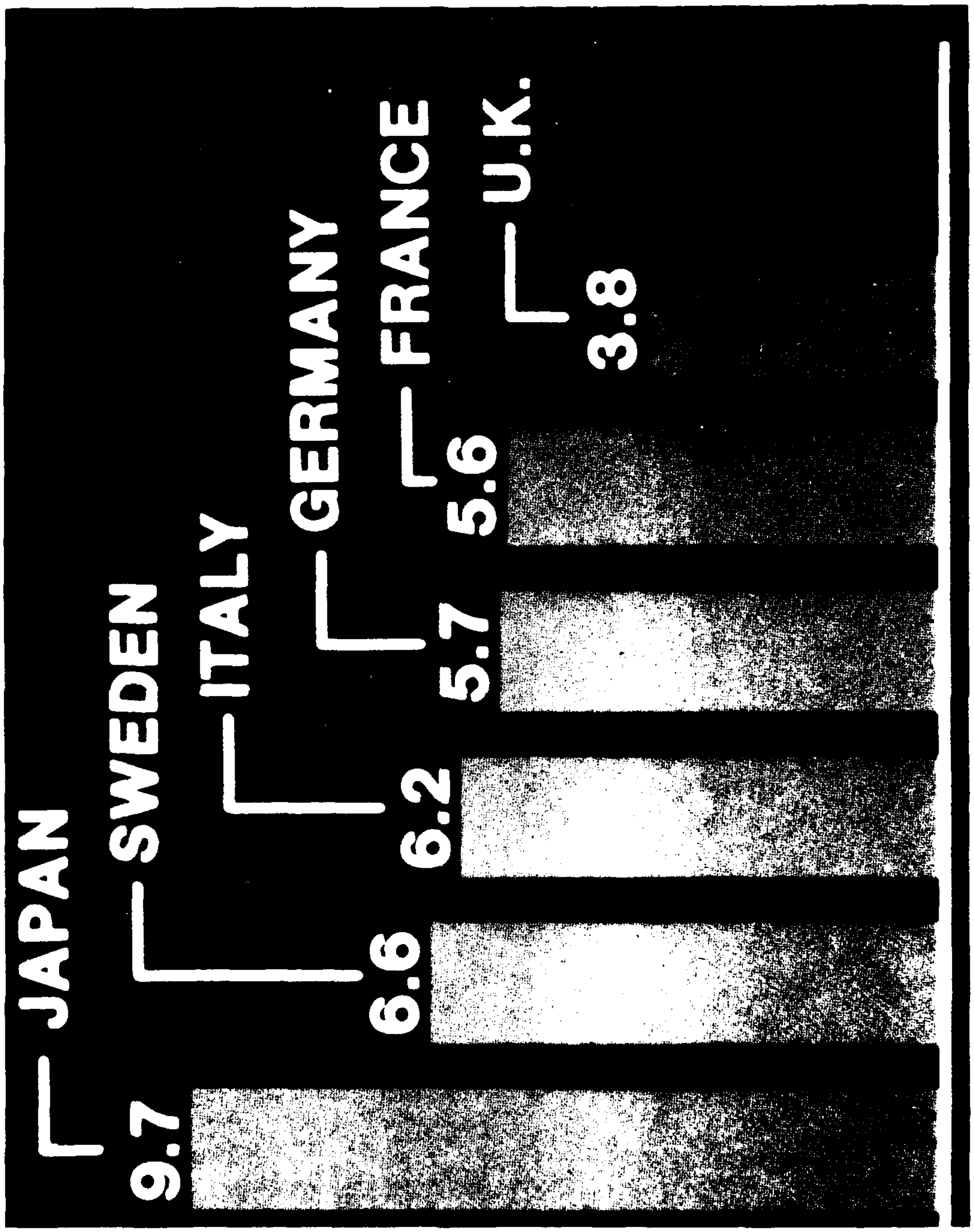

NAVAL AIR SYSTEMS COMMAND

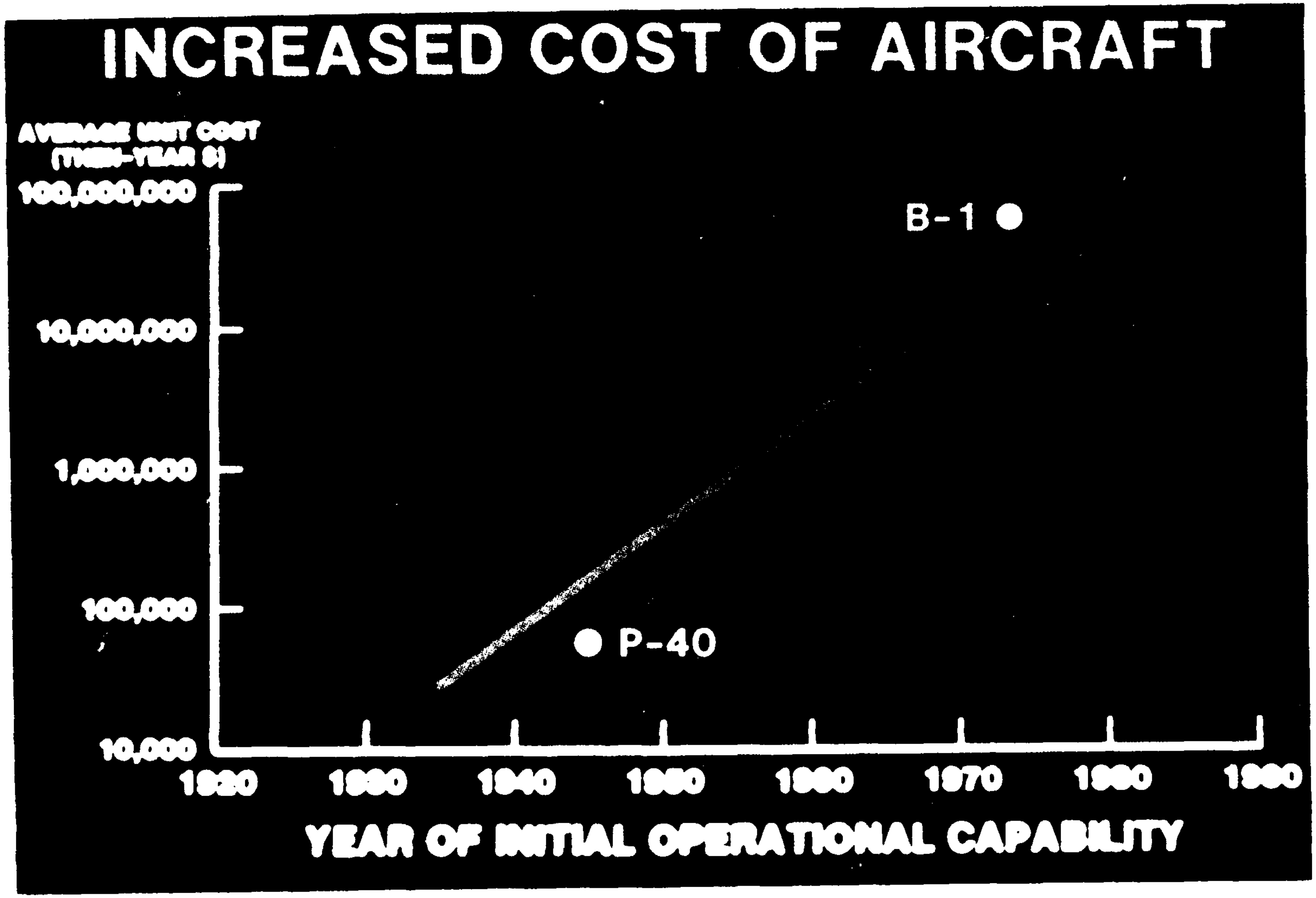

"COMPUTERATED DESIGN"
GO
STOP
REQUIREMENTS

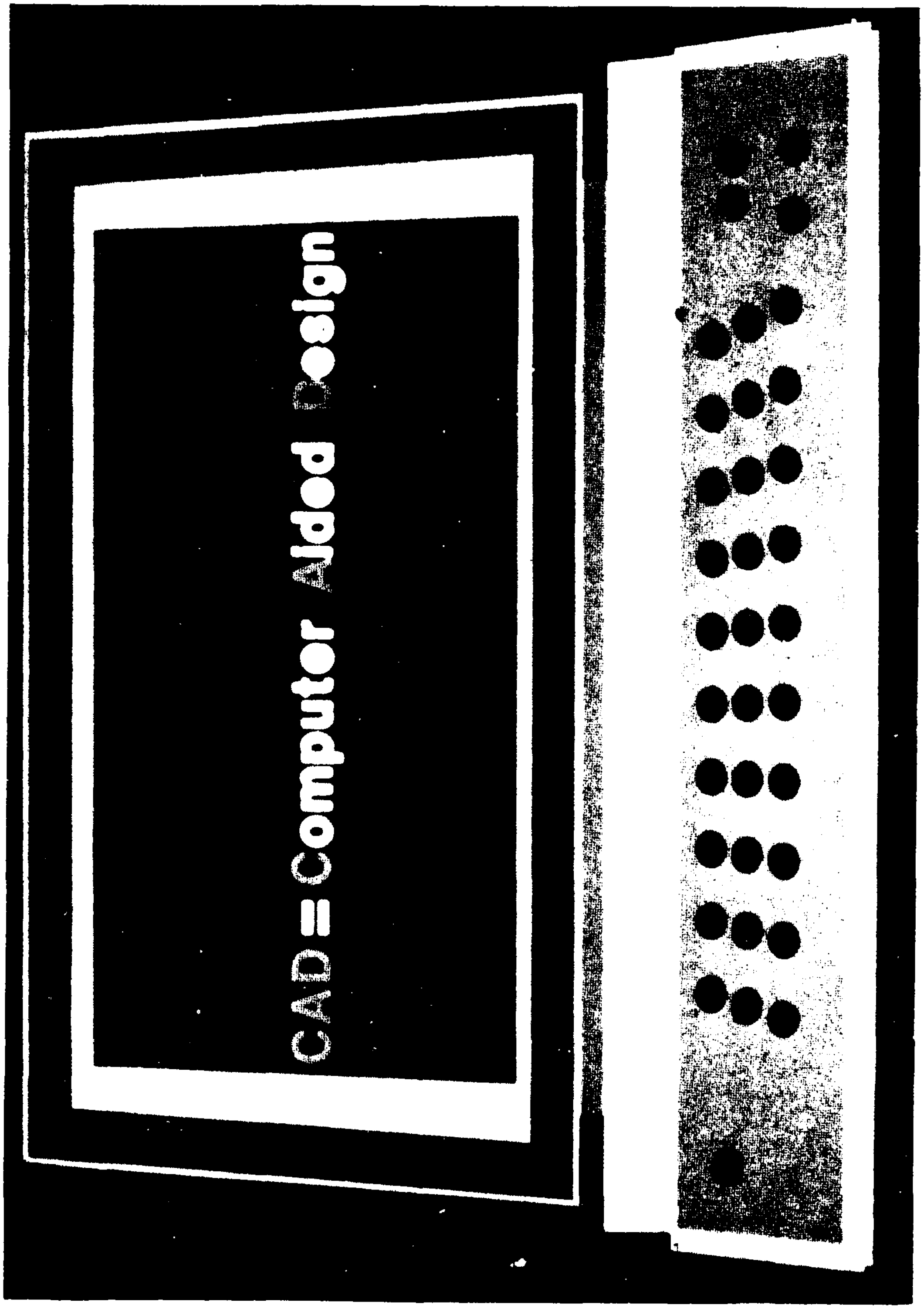

M.P.H.
10,000
5,000
2,000
1,000
500
200
100
50
20
SST
707
DC-3
MUSCLE POWER
MACHINE POWER
5000
BC↔AD
0
1000
1500
1900
TODAY
2000
TIME



IMPLEMENTATION OF TECHNOLOGY (1940-
RELATIVE VOLUME
1.0
1.0
2.4
1.6
5.7
2.5
13.5
4.1
32.0
6.7
1940
1950
1960
1970
1980
GROWTH OF TECHNOLOGY (1940-1980) BASED ON 8 YEAR AVERAGE DOUBLING RATE
IMPLEMENTATION OF TECHNOLOGY (1940-1980) BASED ON 5% ANNUAL GROWTH RATE


JAPAN
9.7
SWEDEN
6.6
ITALY
6.2
GERMANY
5.7
FRANCE
5.6
U.K.
3.8


INCREASED COST OF AIRCRAFT
AVERAGE UNIT COST
(THEN-YEAR $)
100,000,000
10,000,000
1,000,000
100,000
10,000
B-1
P-40
1920
1940
1970
YEAR OF INITIAL OPERATIONAL CAPABILITY


CAD = Computer Aided Design

AEROSPACE INDUSTRY CAPABILITIES
IN INTEGRATED AIRCRAFT DESIGN

- GRUMMAN AEROSPACE CORPORATION
  - RAVES (RAPID AEROSPACE VEHICLE EVALUATION SYSTEM)
    - IBM 360/370
- ROCKWELL INTERNATIONAL - COLUMBUS AIRCRAFT DIVISION
  - BATCH COMPUTER AIDED DESIGN
    - IBM 360/370
- MCDONNELL AIRCRAFT COMPANY
  - CAD/CAM (COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURING)
    - IBM 2250 GRAPHICS ON IBM 360/370
- VOUGHT CORPORATION
  - ASAP (AIRCRAFT SYNTHESIS ANALYSIS PROGRAM)
    - CDC 777 GRAPHICS ON CDC 6600

AEROSPACE INDUSTRY CAPABILITIES
IN INTEGRATED AIRCRAFT DESIGN

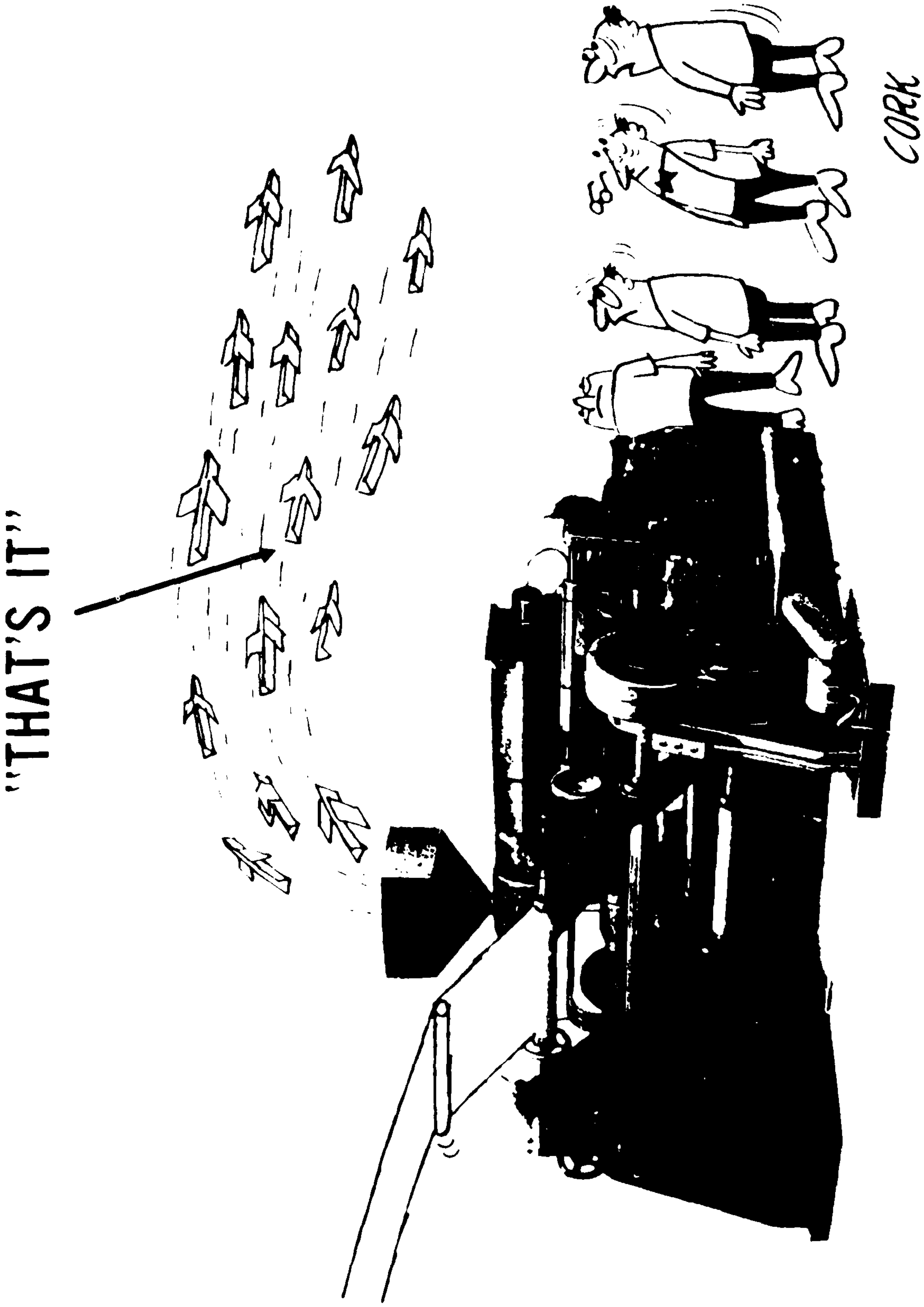
- GENERAL DYNAMICS - CONVAIR DIVISION
  - VDEP (VEHICLE DESIGN AND EVALUATION PROGRAM)
    - CDC CYBER 172 WITH INTERACTIVE GRAPHICS SCOPE
- ROCKWELL INTERNATIONAL - NORTH AMERICAN AIRCRAFT OPERATIONS
  - BATCH COMPUTER AIDED DESIGN
    - IBM 360/370
- LOCKHEED AIRCRAFT CORPORATION
  - CADM (COMPUTER AIDED DESIGN AND MANUFACTURING)
    - IBM 360/370
- DOUGLAS AIRCRAFT CORPORATION
  - ADVANCED DESIGN SIZING PROCEDURE
    - IBM 360/370
- NASA AMES RESEARCH CENTER
  - GASP (GENERAL AVIATION SYNTHESIS PROGRAM)
    - TEKTRONIX SCOPE ON IBM 360 (BEING TRANSFERRED TO CDC 7600)

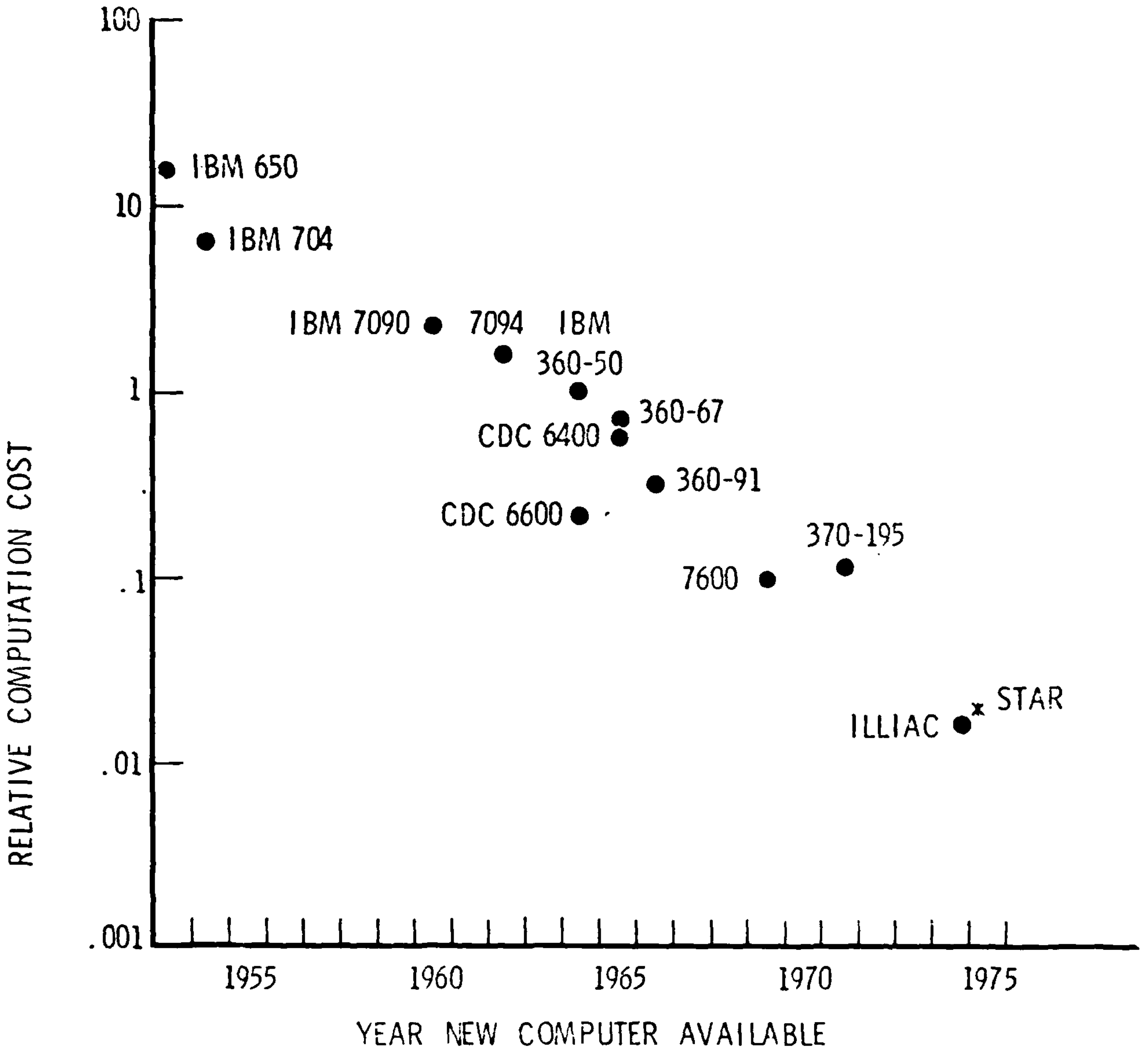
THE PROBLEM

- GREATLY INCREASED WORKLOAD
- SHORTENED RESPONSE TIME
- REDUCED NUMBERS OF PERSONNEL
- INEFFICIENT USE OF CRITICAL SKILLS

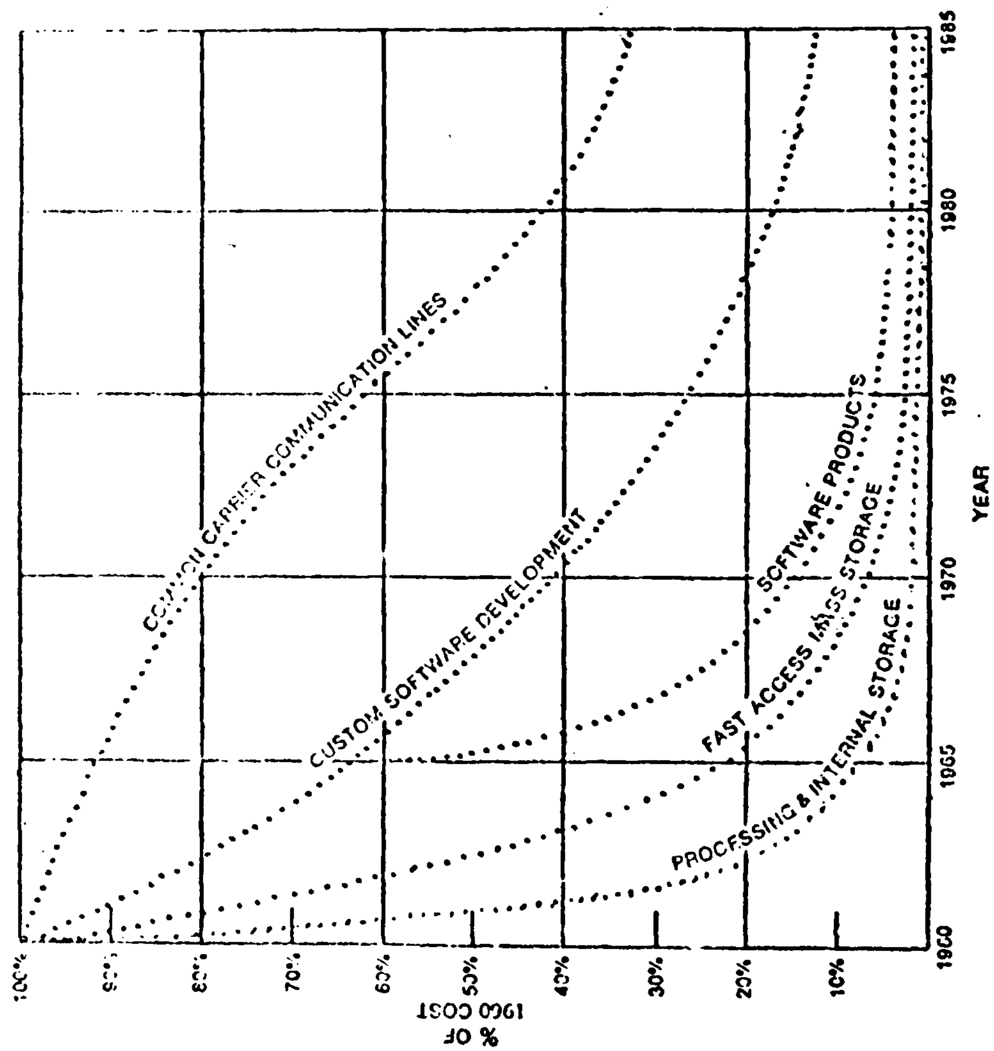
MATACQINST 13100.1

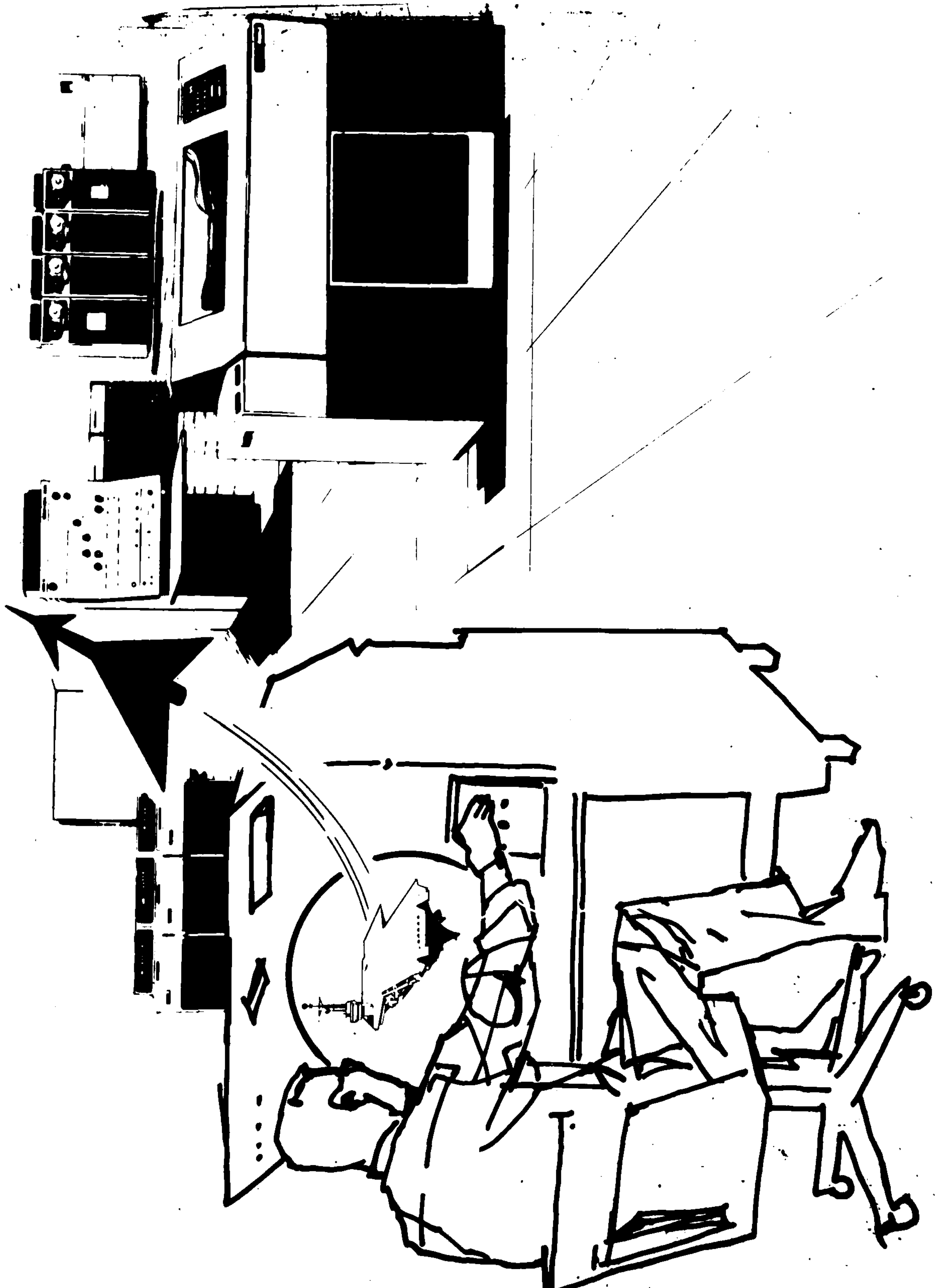
"-----PROVIDES THE POLICY AND PROCEDURES TO ESTABLISH AND IMPLEMENT A COMPUTER-AIDED AIRCRAFT AND MISSILE CONCEPTUAL DESIGN SYSTEM IN THE MATERIAL ACQUISITION GROUP."


"THAT'S IT"
CORK



Trend of computation cost for computer simulation of a given flow

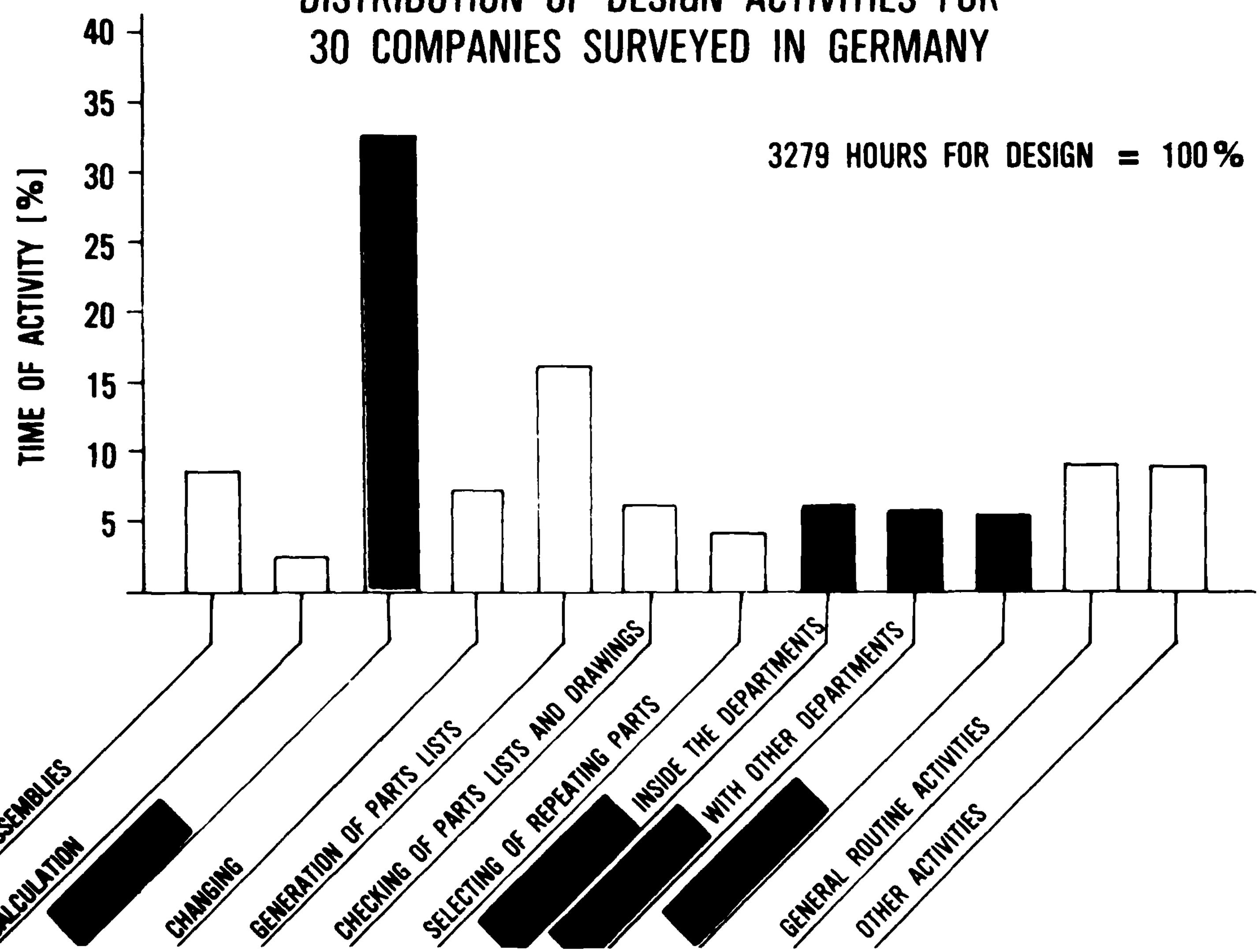

COMMON CARRIER COMMUNICATION LINES
CUSTOM SOFTWARE DEVELOPMENT
SOFTWARE PRODUCTS
FAST ACCESS MASS STORAGE
PROCESSING & INTERNAL STORAGE
% OF 1960 COST
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
1960
1965
1970
1975
1980
1985
YEAR



INTEGRATED COMPUTER AIDED DESIGN

DISTRIBUTION OF DESIGN ACTIVITIES FOR
30 COMPANIES SURVEYED IN GERMANY

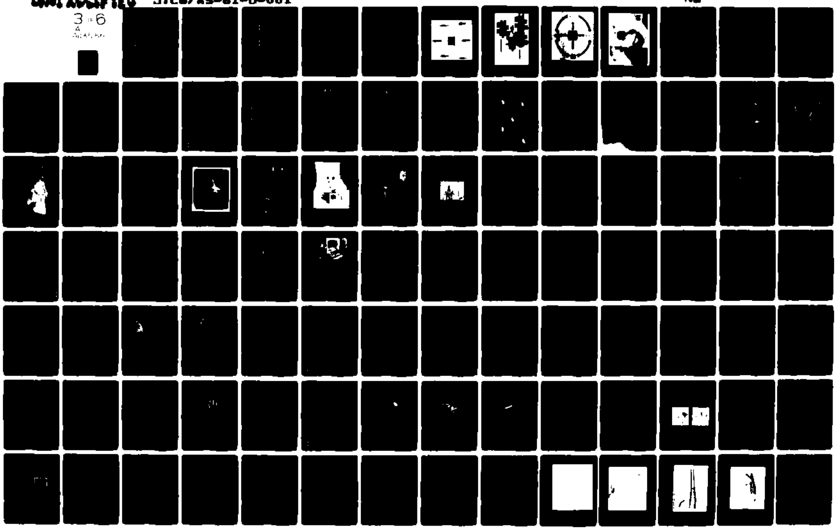
3279 HOURS FOR DESIGN = 100 %



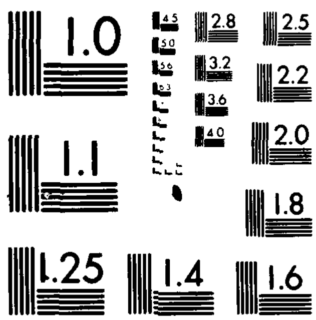
AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981

UNCLASSIFIED JTCG/AS-81-D-001 NL

3 of 6



LUNG



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

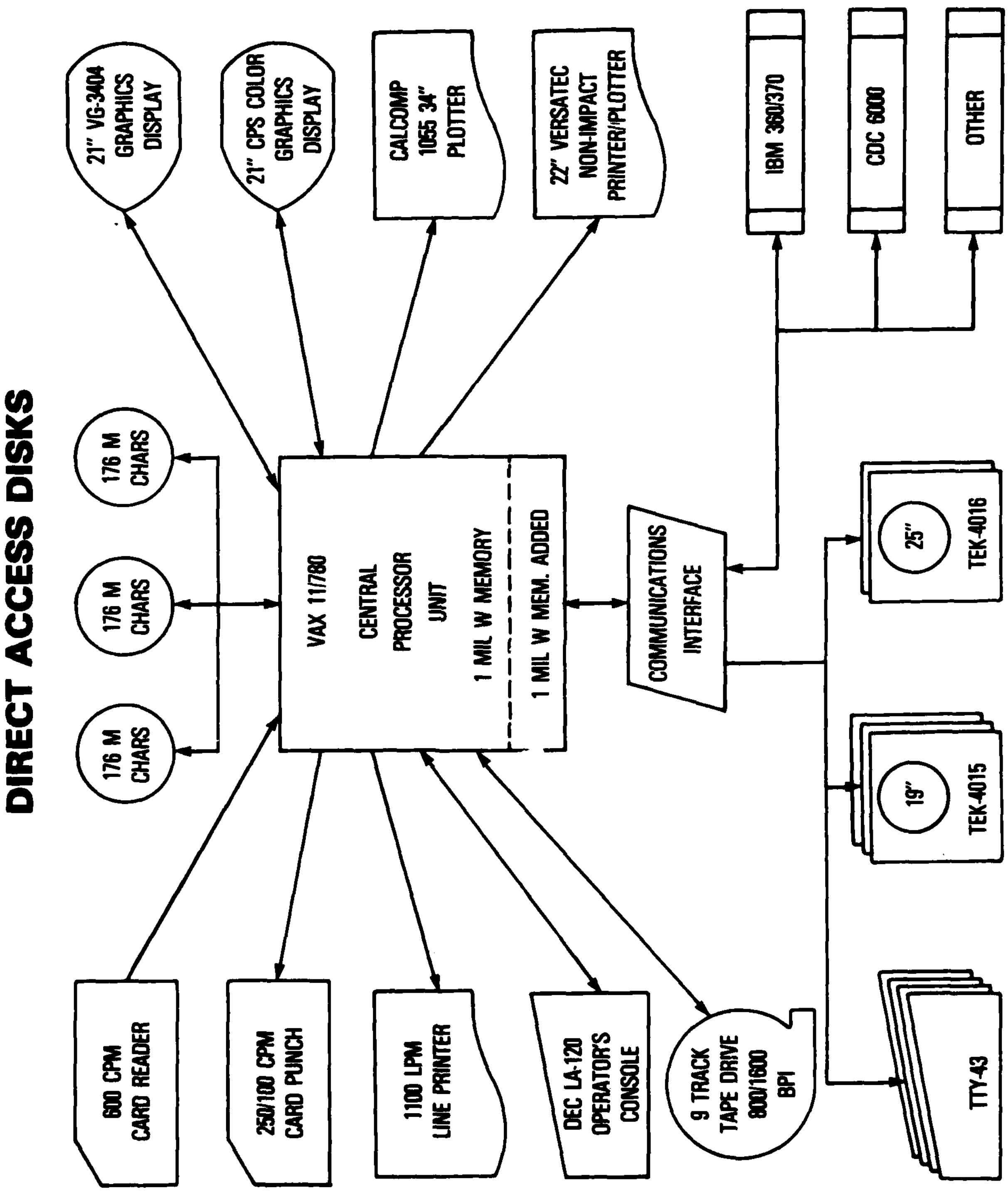
AIRCRAFT

CONTRACTOR PROGRAMS ACQUIRED

- ASAP (LTV - FIGHTER/ATTACK
- VDEP (GENERAL DYNAMICS) - TRANSPORT
- ACSYNT (NASA) - UNUSUAL CONFIGURATIONS
- GASP (NASA) - LIGHT AIRCRAFT
- CDS (ROCKWELL) - GRAPHICS DESIGN

IN-HOUSE PROGRAM GENERATION

- NASP - FIGHTER/ATTACK
  - TRANSPORT
  - TRAINER
  - ?


DIRECT ACCESS DISKS
176 M CHARS
176 M CHARS
176 M CHARS
VAX 11/780
CENTRAL PROCESSOR UNIT
1 MIL W MEMORY
1 MIL W MEM. ADDED
21" VG-3404 GRAPHICS DISPLAY
21" CPS COLOR GRAPHICS DISPLAY
CALCOMP 1055 34" PLOTTER
22" VERSATEC NON-IMPACT PRINTER/PLOTTER
IBM 360/370
CDC 6000
OTHER
COMMUNICATIONS INTERFACE
25"
TEK-4016
19"
TEK-4015
TTY-43
600 CPM CARD READER
250/100 CPM CARD PUNCH
1100 LPM LINE PRINTER
DEC LA-120 OPERATOR'S CONSOLE
9 TRACK TAPE DRIVE 800/1600 BPI

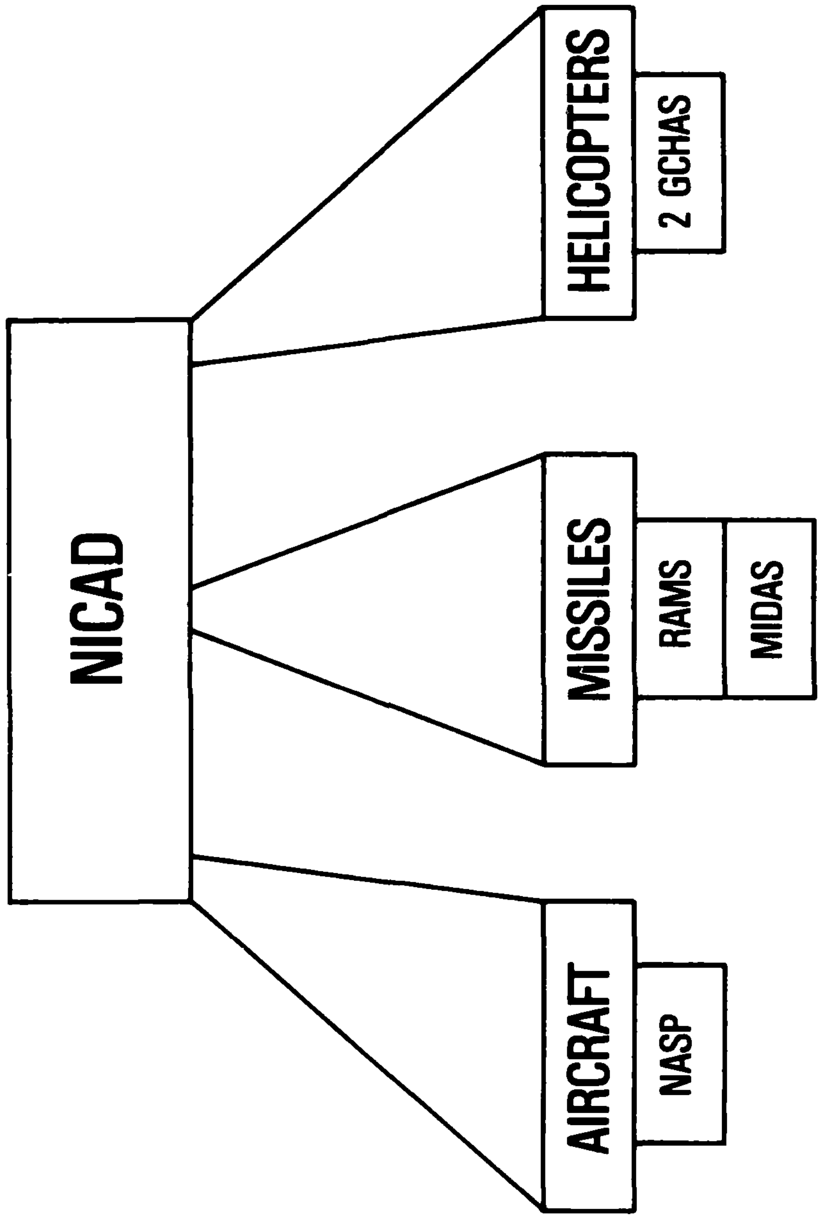
NAVAIR WILL SOON BE:

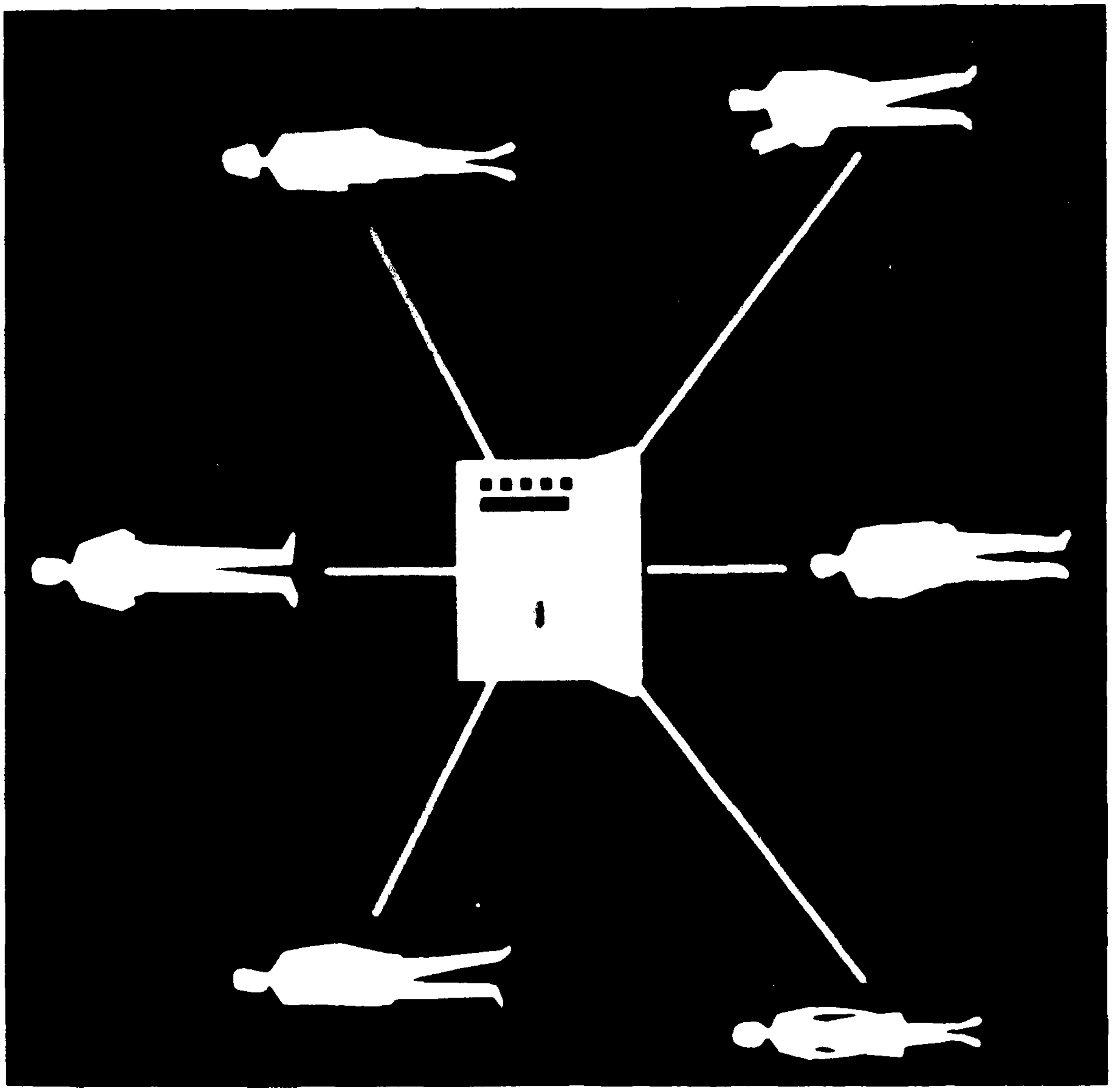
- UNABLE TO PASS JUDGEMENT ON FUTURE DESIGNS
- LOSING GROUND RELATIVE TO INDUSTRY IN TECHNOLOGY DEVELOPMENTS
- UNABLE TO RESPOND IN TIMELY FASHION TO WORK REQUESTED BY HIGHER AUTHORITY

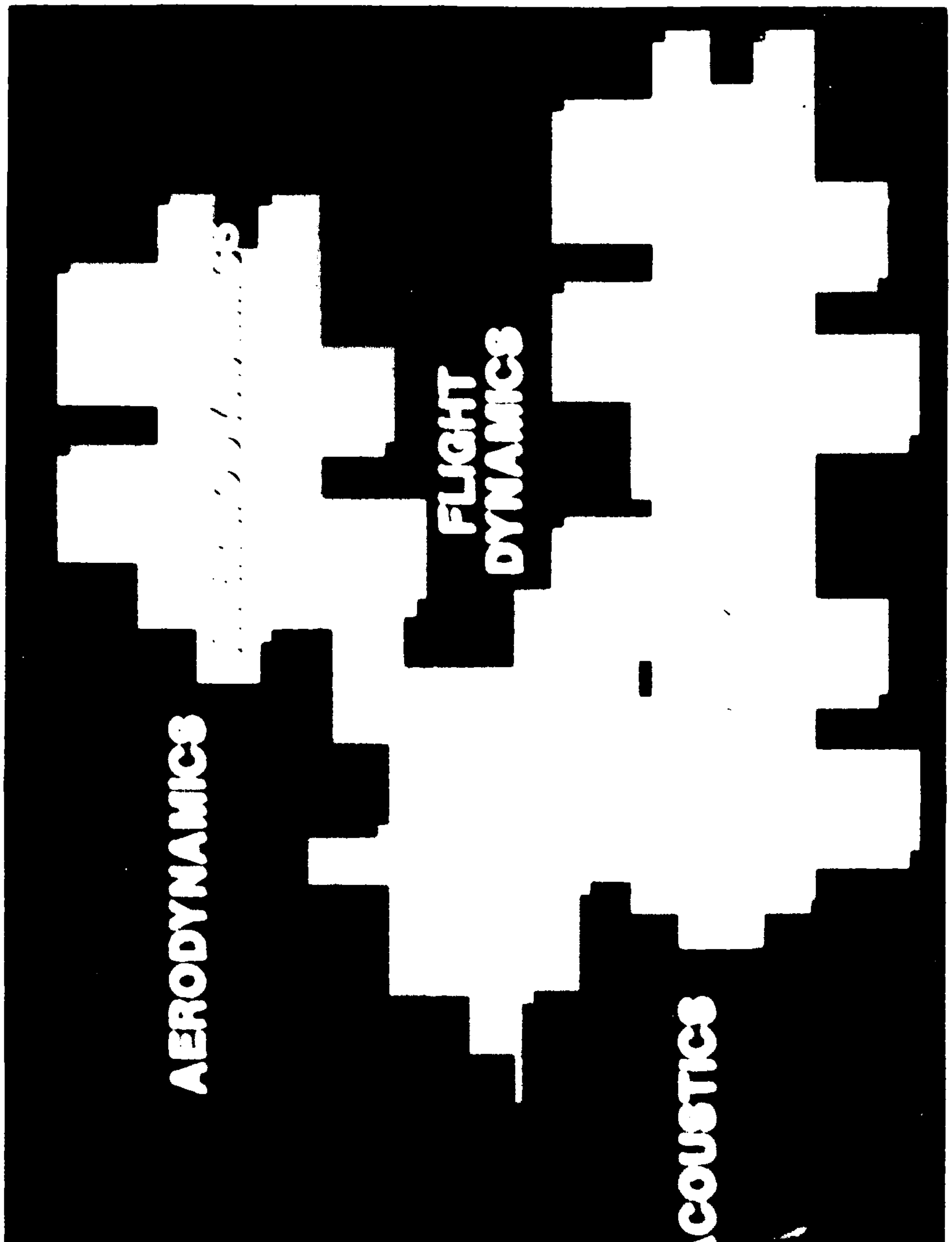
NICAD★

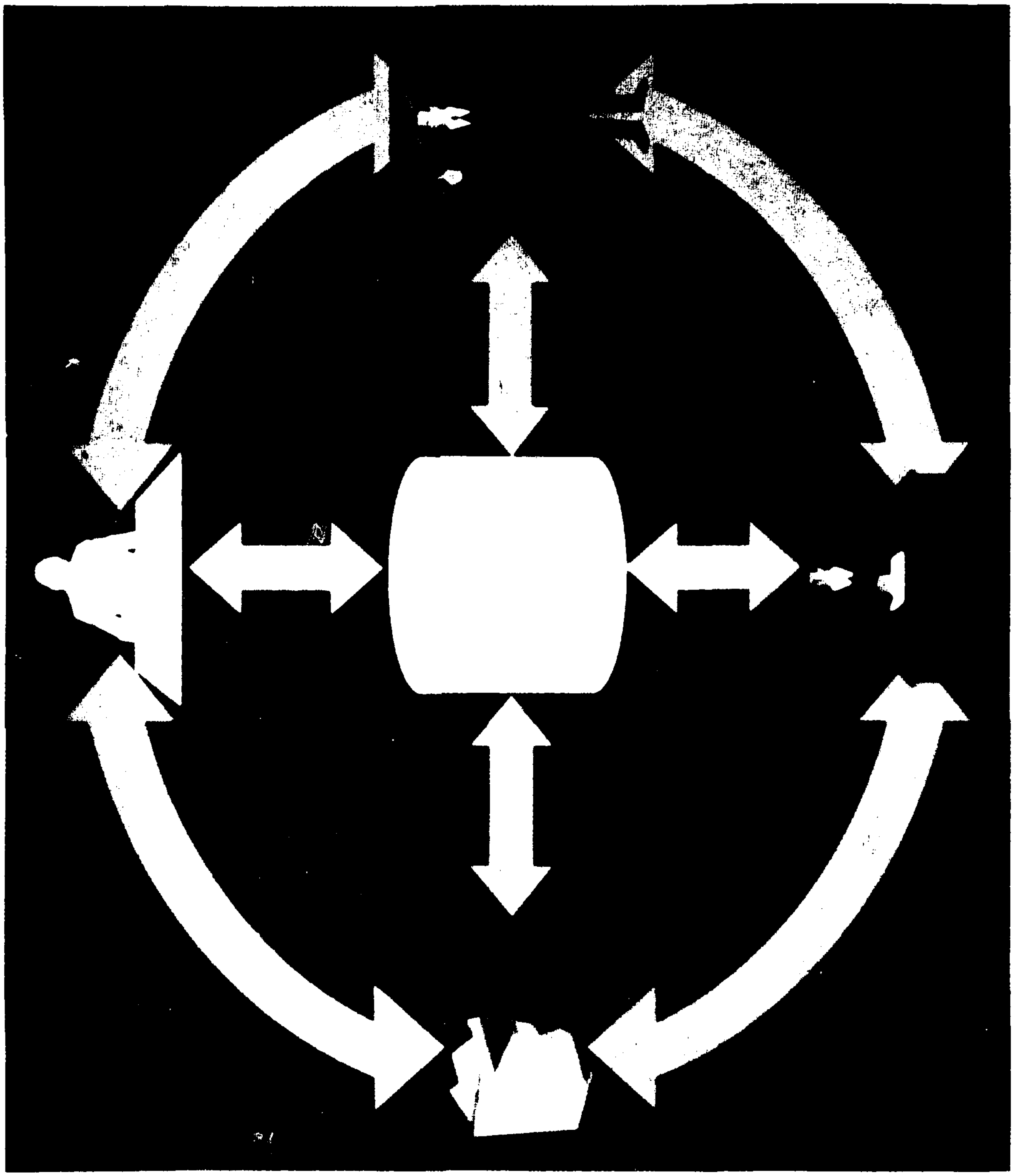
A NAVAIR RESOURCE FOR INCREASED PRODUCTIVITY

★ NAVAIR INTEGRATED COMPUTER-AIDED DESIGN

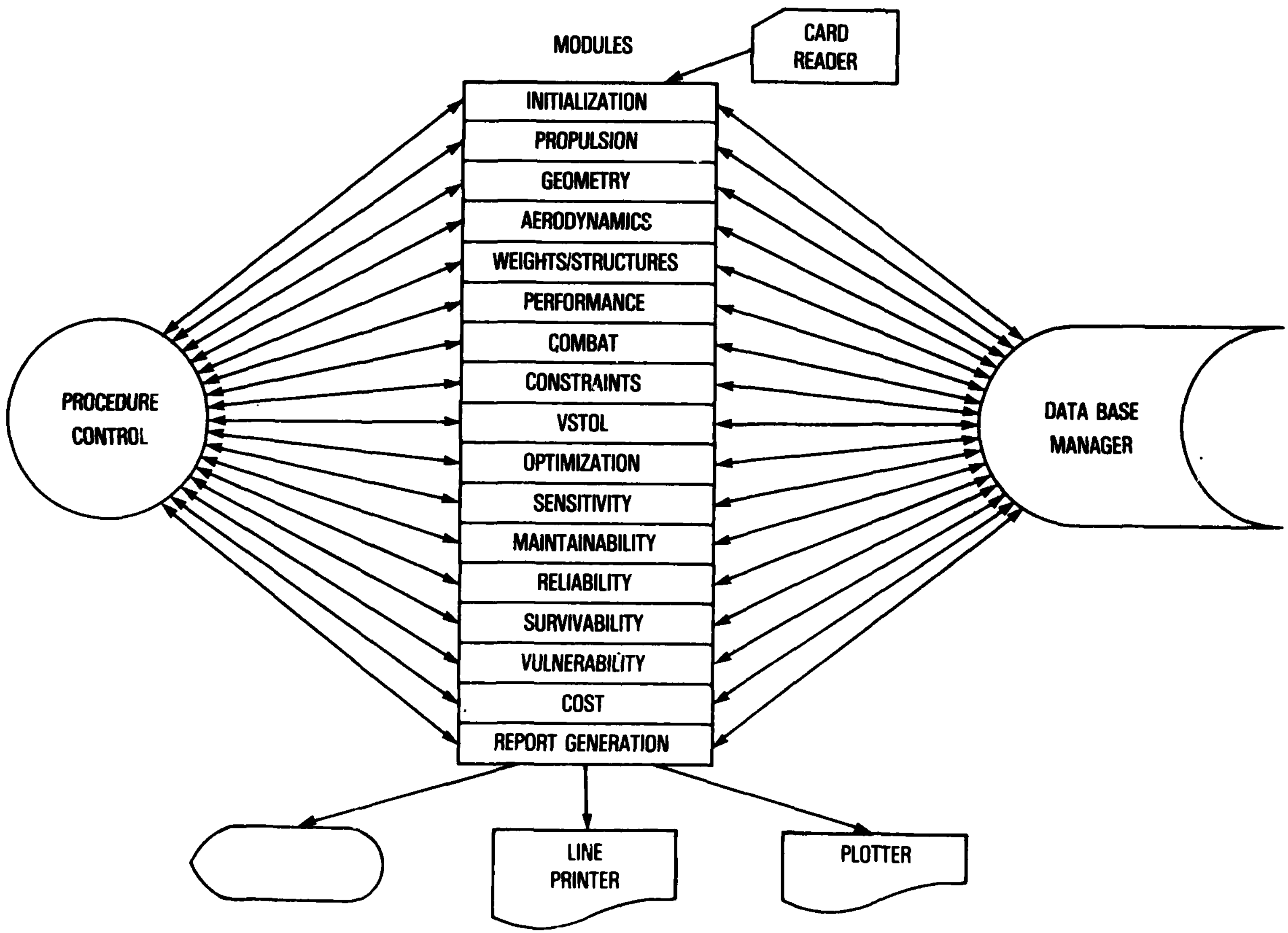

NICAD
AIRCRAFT
NASP
MISSILES
RAMS
MIDAS
HELICOPTERS
2 GCHAS




AERODYNAMICS
FLIGHT DYNAMICS
ACOUSTICS



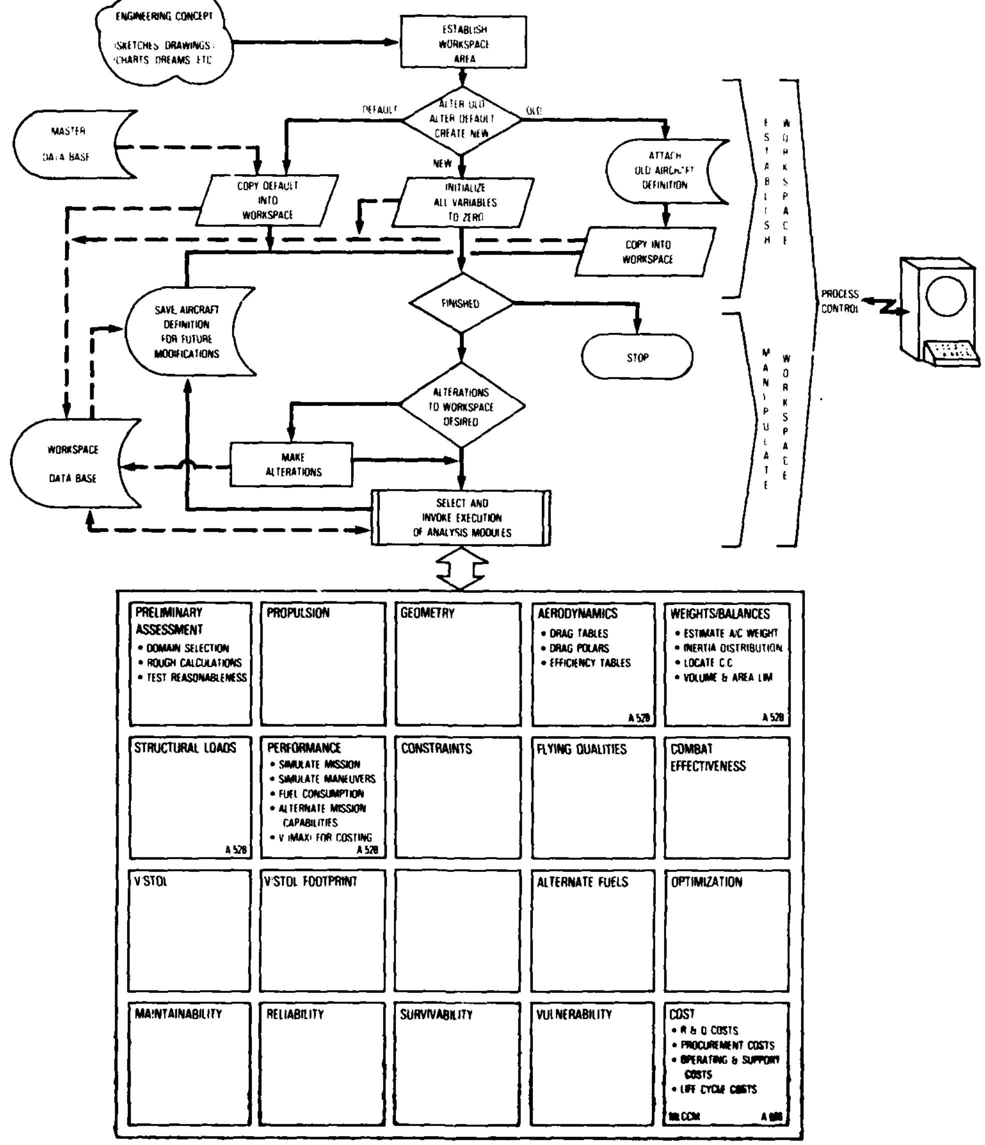
NAVAIR AIRCRAFT SYNTHESIS PROGRAM (NASP)



NASP PROGRAM

- MODULAR CONSTRUCTION
- EXTENSIVE DATA BASE
- ALL TECHNICAL DISCIPLINES INVOLVED
- TWO LEVEL OPERATING MODE
- BASED ON EXISTING PROGRAMS
  - LTV (ASCAP)
  - GD (VDEP)
  - NASA (ACSYNT)
  - ROCKWELL (CDS)
- DYNAMIC PROGRAM
  - EASY TO CHANGE
  - VERY READABLE

NAVAIR AIRCRAFT SYNTHESIS PROGRAM (NASP)



Q: ARE YOU GOING TO BUILD A NEW AIRCRAFT DEFINITION OR ARE YOU GOING TO USE AN EXISTING AIRCRAFT DEFINITION?

BUILD-THIS ALLOWS YOU TO BUILD A NEW AIRCRAFT DEFINITION. YOU MAY USE A SPECIFIC AIRCRAFT DEFINITION, THE SYSTEM DEFAULT, OR YOU MAY BUILD YOUR OWN.

EXIST-THIS ALLOWS YOU TO USE AN EXISTING AIRCRAFT DEFINITION.

A: BUILD

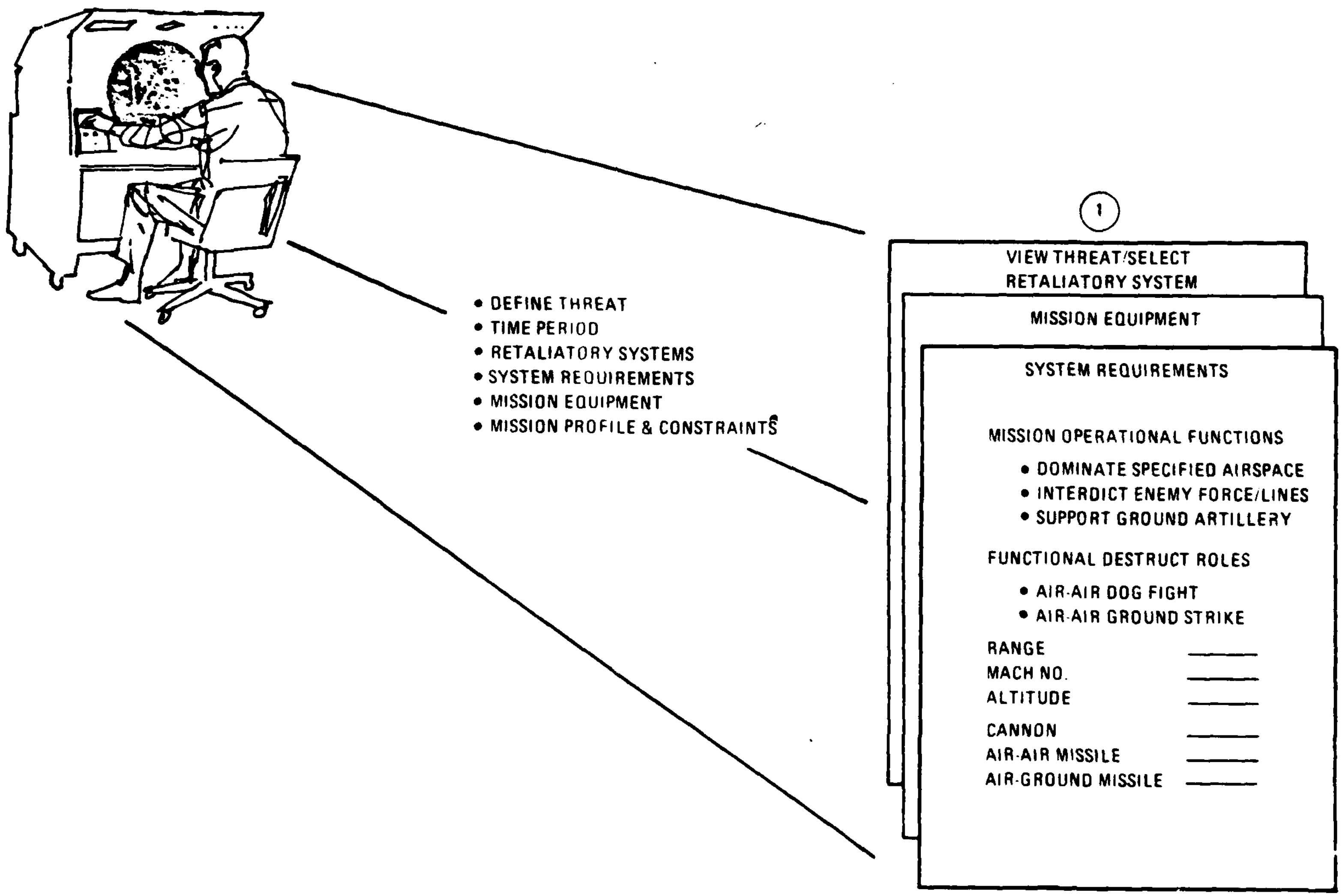
Q: WHAT TYPE OF AIRCRAFT ARE YOU GOING TO BUILD?

TYPE XS - THE SPECIFIC TYPE FROM THE SYSTEM DATA BASE IS USED.
DEFAULT - THE SYSTEM DEFAULT AIRCRAFT DEFINITION IS USED.
NULL - A NULL AIRCRAFT DEFINITION IS CREATED. THIS ALLOWS YOU TO CREATE YOUR OWN AIRCRAFT DEFINITION.
LI - THIS LISTS ALL THE POSSIBLE TYPES OF AIRCRAFT DEFINITIONS YOU CAN CHOOSE FROM.

A: LI
0000000002
THIS IS AN A-4 TEST AIRCRAFT

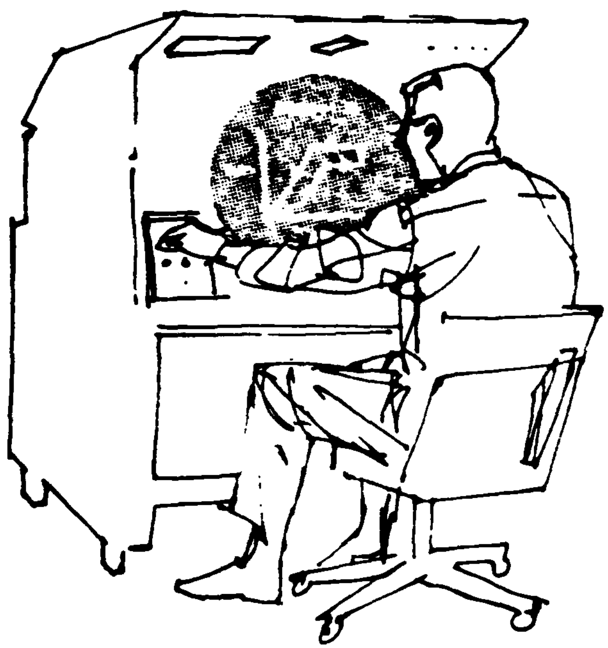
Q: YOU NOW HAVE AN AIRCRAFT DEFINITION TO ANALZYE.
WHAT UPDATE FUNCTION DO YOU WANT TO PERFORM AGAINST YOUR AIRCRAFT DEFINITION?

MERGE - ALLOWS YOU TO REPLACE ANY DATA GROUPS IN YOUR AIRCRAFT DEFINITION FROM ANOTHER AIRCRAFT DEFINITION.
GRPCHG - ALLOWS YOU TO REPLACE ANY DATA GROUP IN YOUR AIRCRAFT DEFINITION FROM THE SYSTEM DATA BASE.
VARGHG - ALLOWS YOU TO REPLACE ANY DATA ELEMENT WITH A NEW VALUE.
END - TERMINATE THIS COMMAND.



• DEFINE THREAT
• TIME PERIOD
• RETALIATORY SYSTEMS
• SYSTEM REQUIREMENTS
• MISSION EQUIPMENT
• MISSION PROFILE & CONSTRAINTS
1
VIEW THREAT/SELECT RETALIATORY SYSTEM
MISSION EQUIPMENT
SYSTEM REQUIREMENTS
MISSION OPERATIONAL FUNCTIONS
• DOMINATE SPECIFIED AIRSPACE
• INTERDICT ENEMY FORCE/LINES
• SUPPORT GROUND ARTILLERY
FUNCTIONAL DESTRUCT ROLES
• AIR-AIR DOG FIGHT
• AIR-AIR GROUND STRIKE
RANGE
MACH NO.
ALTITUDE
CANNON
AIR-AIR MISSILE
AIR-GROUND MISSILE

① MISSION DEFINITION



- DEFINE THREAT
- TIME PERIOD
- RETALIATORY SYSTEM
- SYSTEM REQUIREMENTS
- MISSION EQUIPMENT
- MISSION PROFILE & CONSTRAINTS

② SELECT CONFIGURATION PARAMETERS & SYNTHESIZE

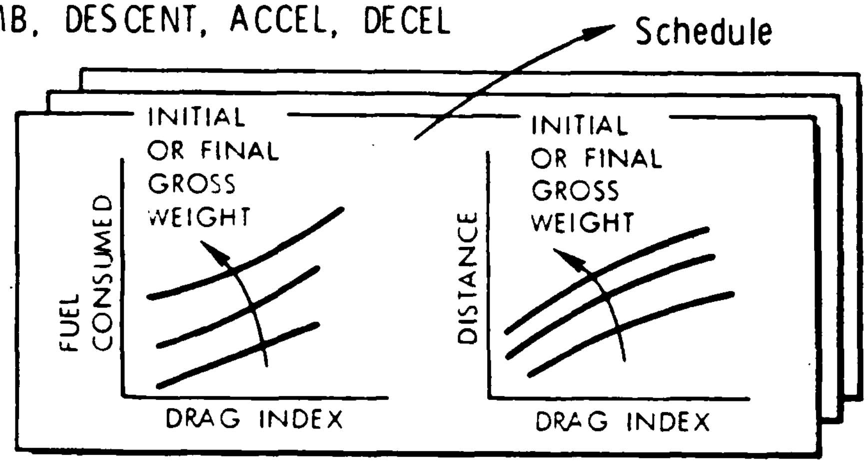
SYNTHESIS

- GEOMETRY
- MASS PROPERTIES
- AERODYNAMICS
- PROPULSION
- STRUCTURES
- ACCELERATION LIMITS

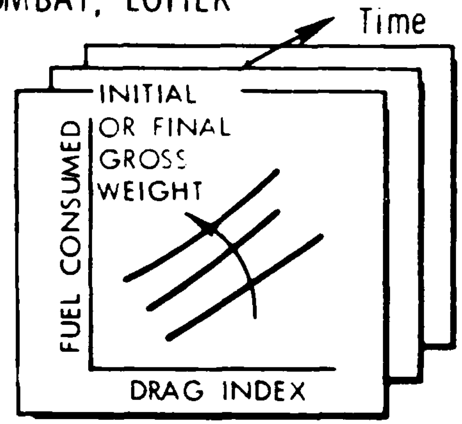
STANDARD MISSION SEGMENTS

- TAKEOFF
- LANDING
- DROP
- CRUISE
- DASH
- COMBAT
- LOITER
- CLIMB
- DESCENT
- ACCELERATION
- DECELERATION
- REFUEL

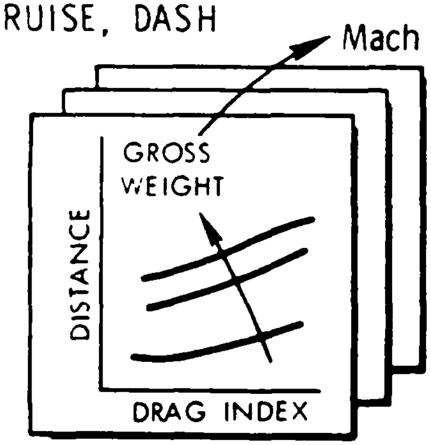
CLIMB, DESCENT, ACCEL, DECEL



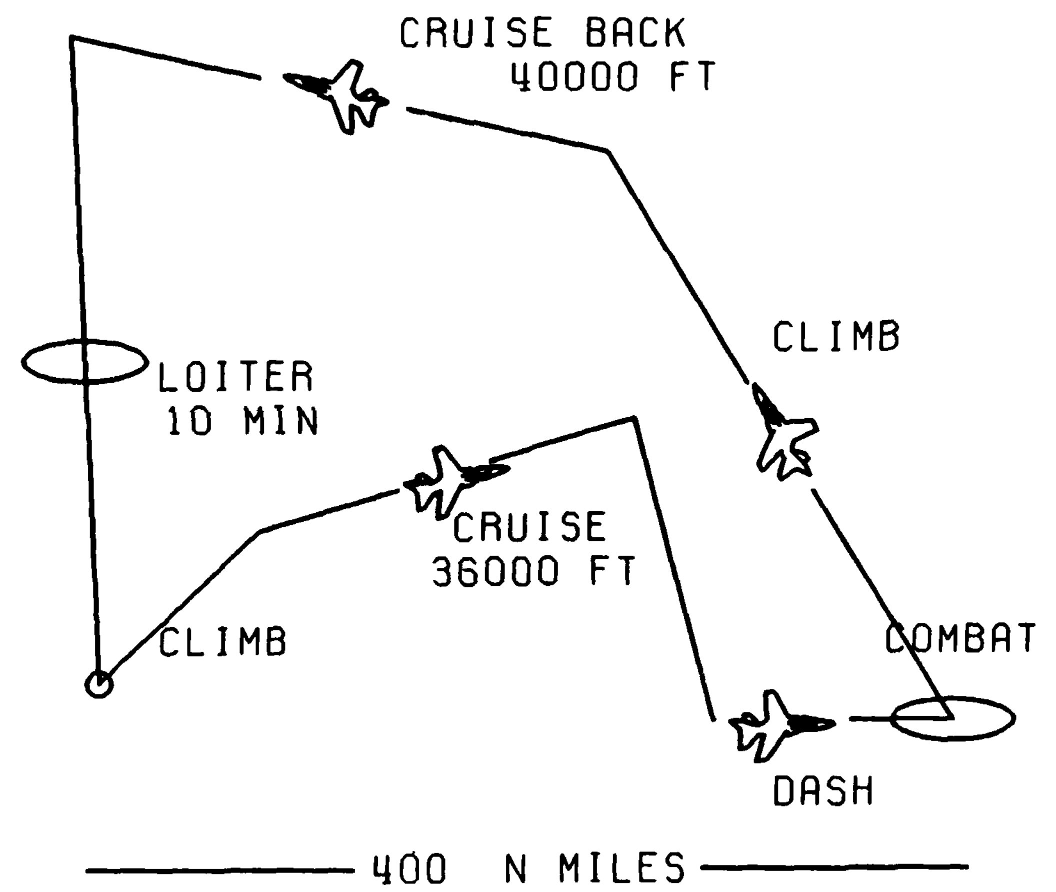
COMBAT, LOITER

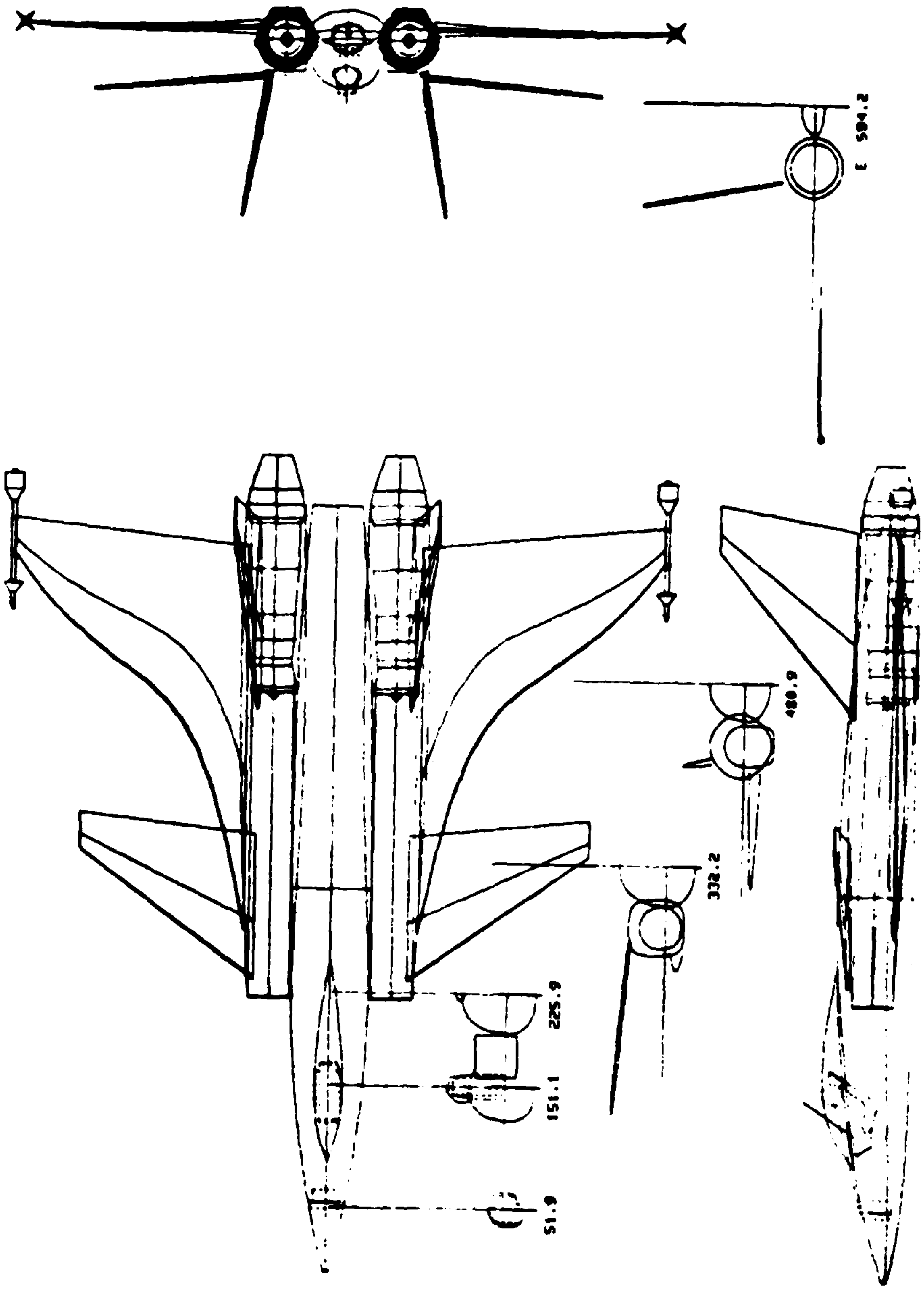


CRUISE, DASH

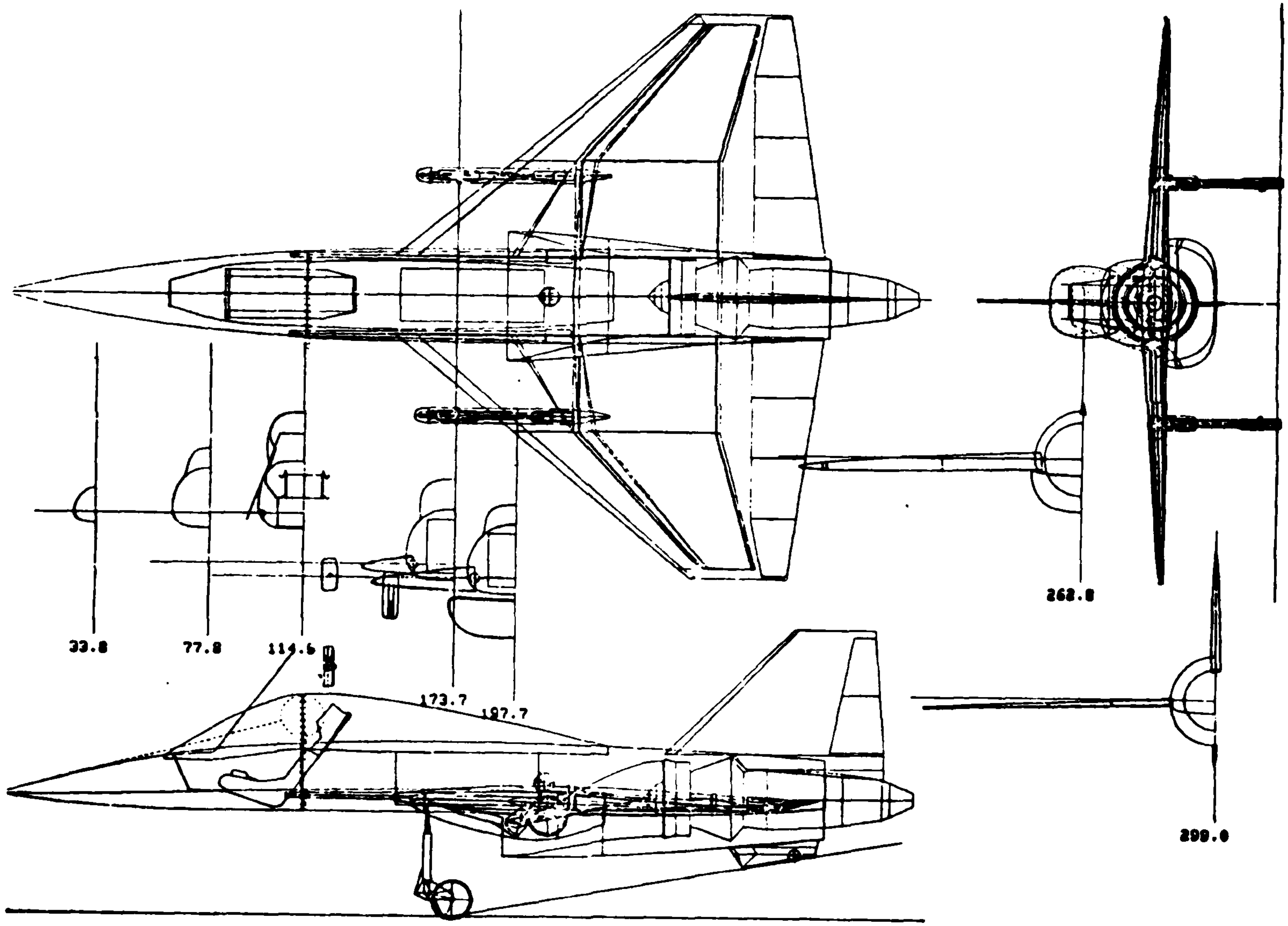


DESIGN MISSION PROFILE

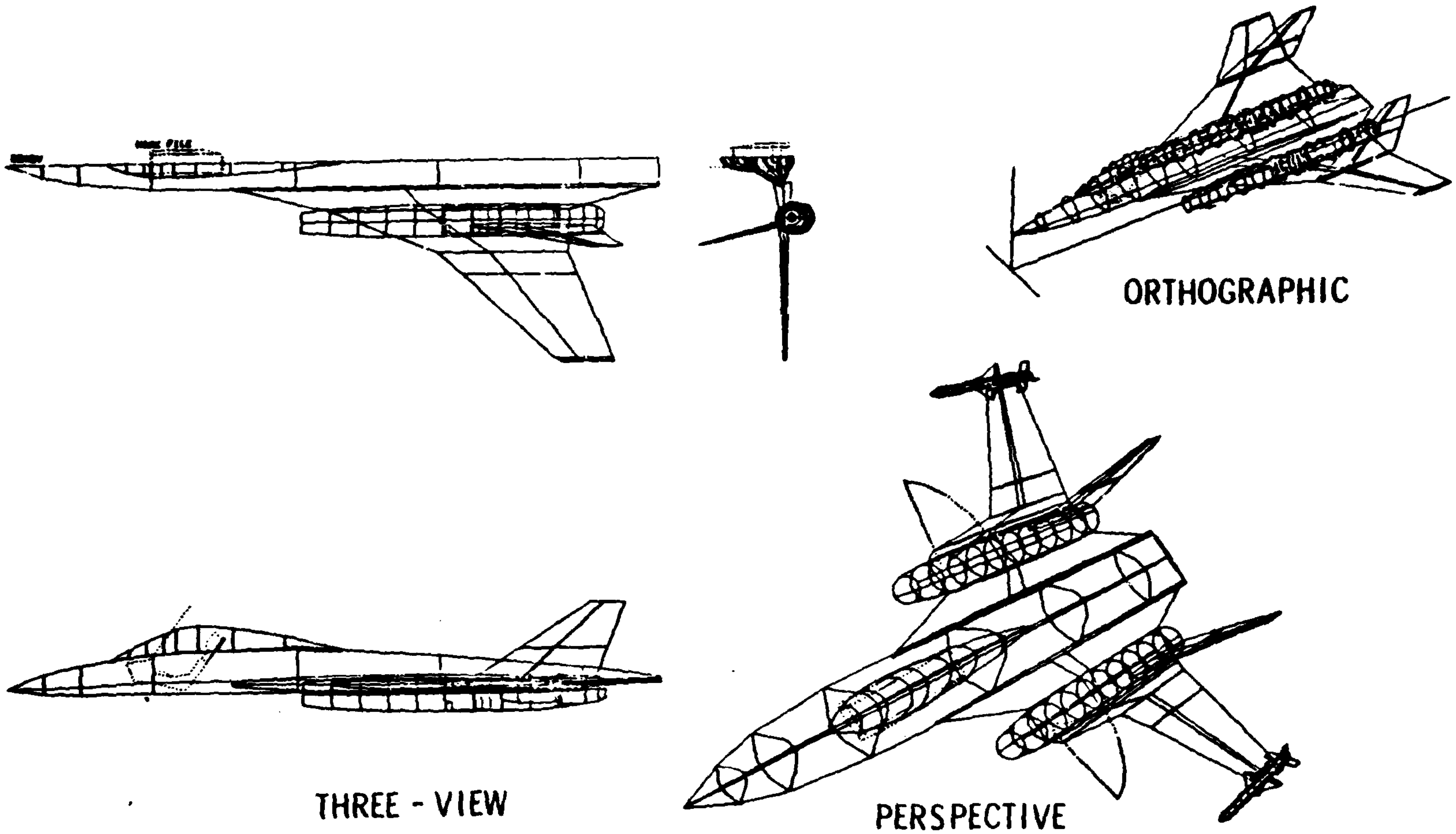



584.2
480.9
332.2
225.9
151.1
51.9

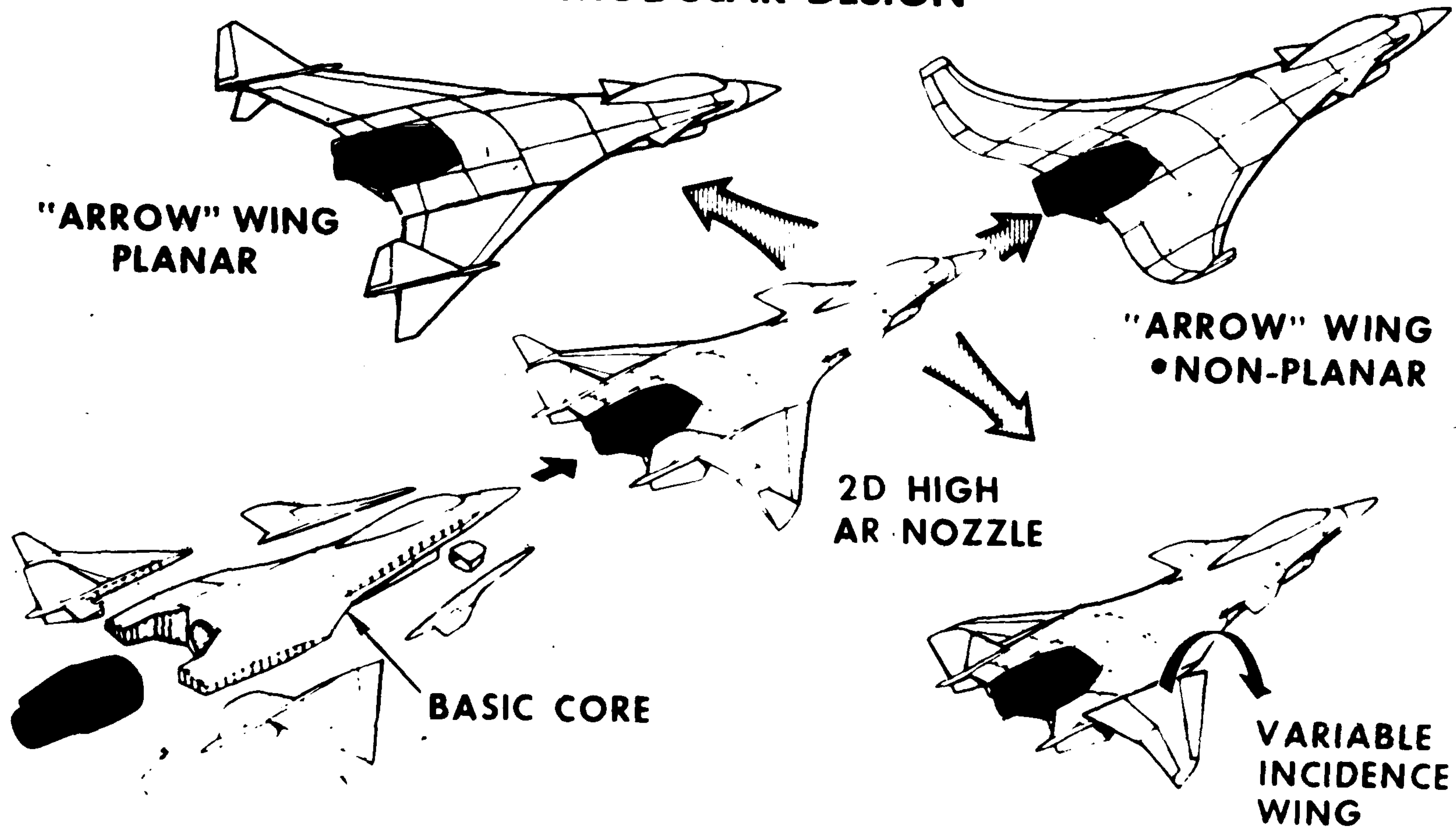
3-VIEW WITH SECTIONS



DISPLAY OPTIONS

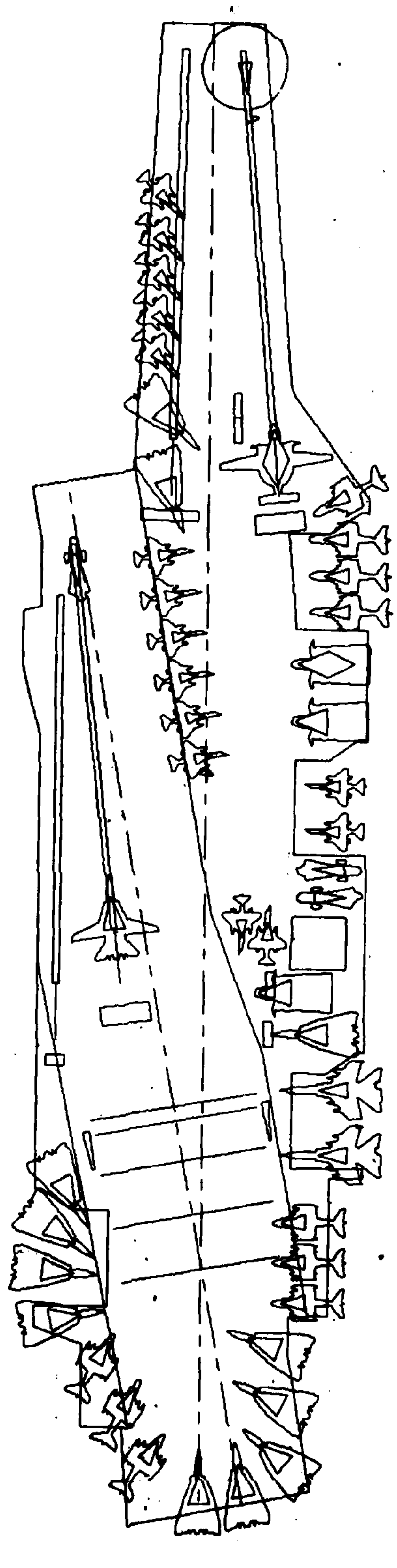


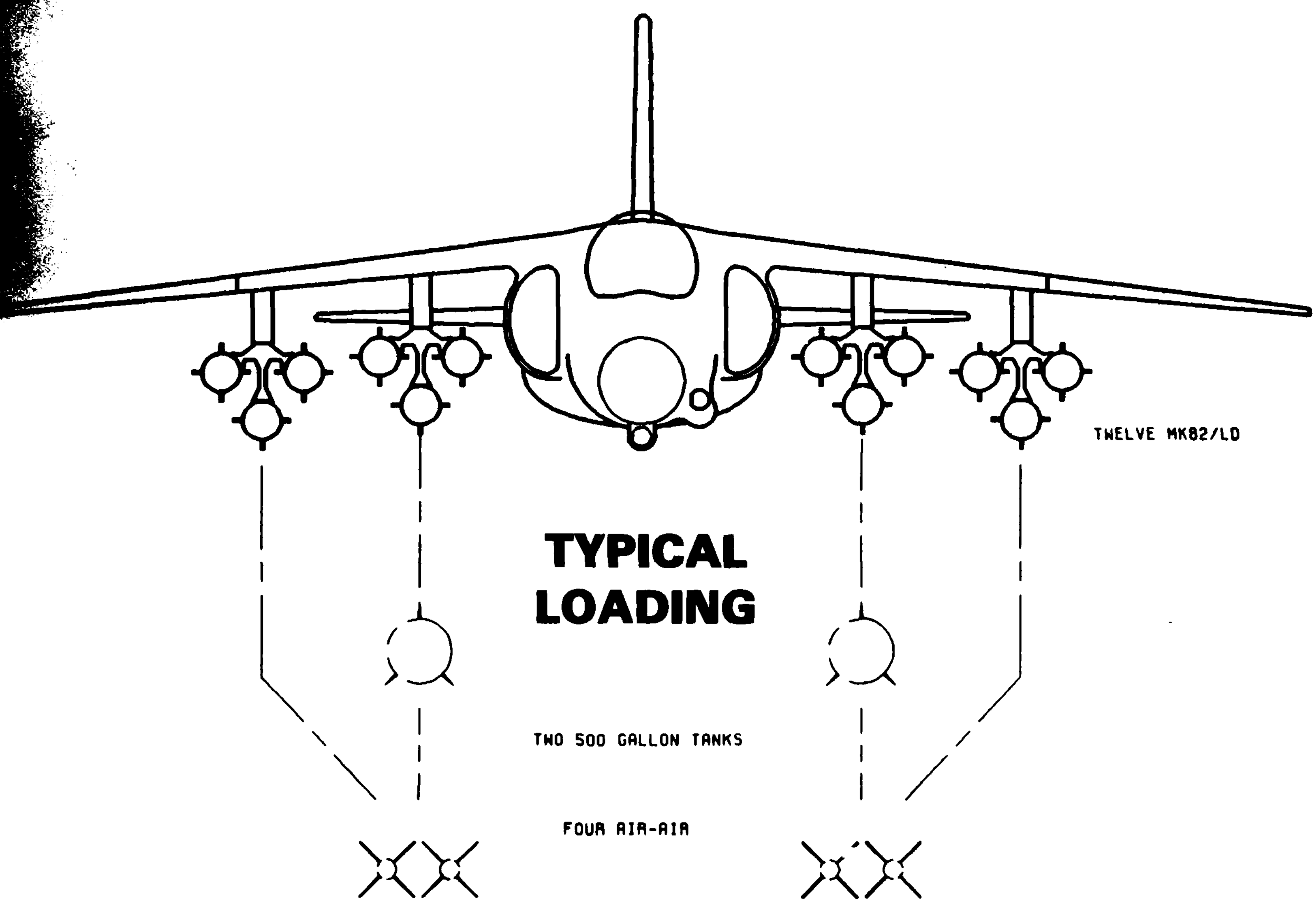
RESEARCH FUTURE POTENTIAL
MODULAR DESIGN



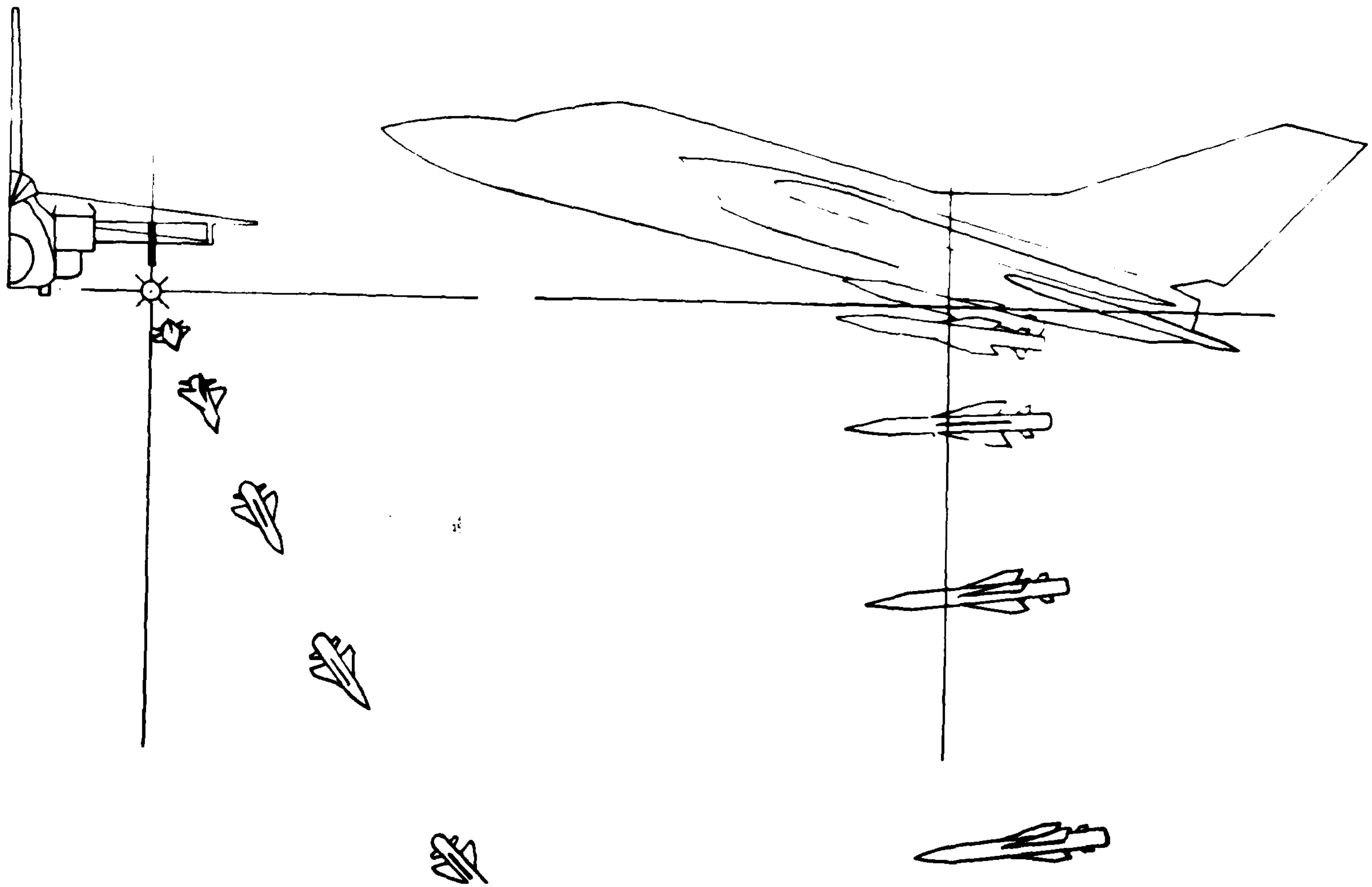
LOW-COST FLIGHT RESEARCH "TOOL" BRIDGING GAP BETWEEN WIND TUNNEL & INCREASINGLY EXPENSIVE MANNED FLIGHT TEST

CVA FLIGHT ENTERPRISE · CVAN 65



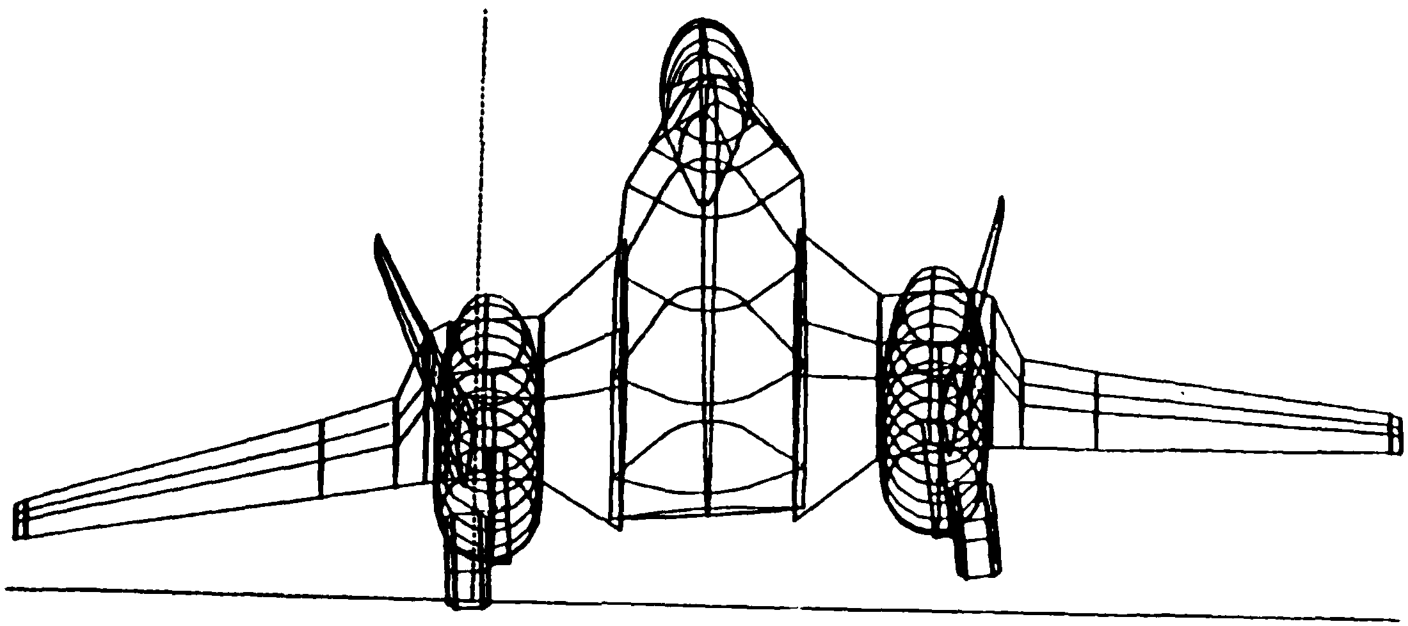

TWELVE MK82/LD
TYPICAL
LOADING
TWO 500 GALLON TANKS
FOUR AIR-AIR

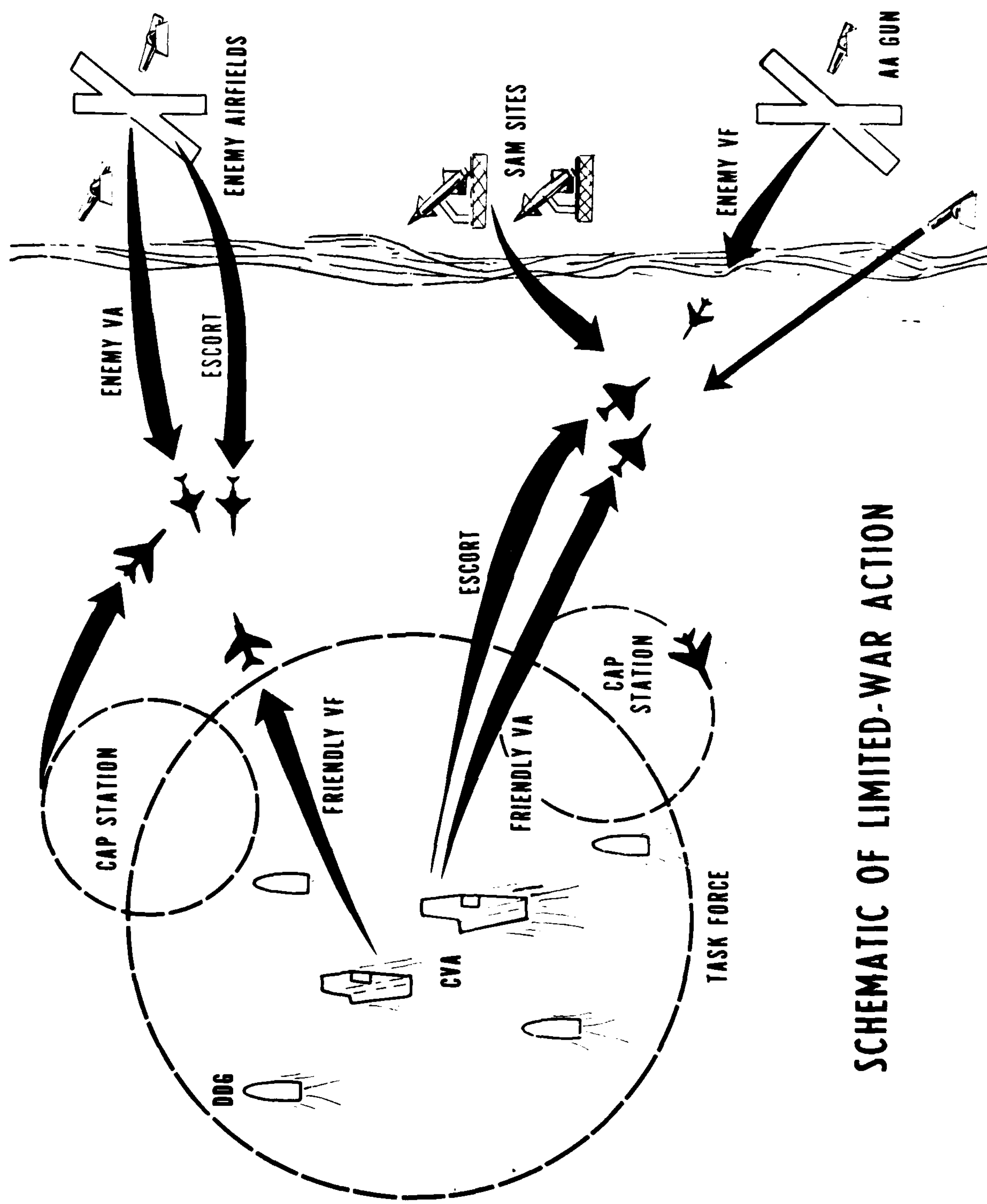
MATCHING OF WINDTUNNEL JETTISON CASE 1399 AT AIT



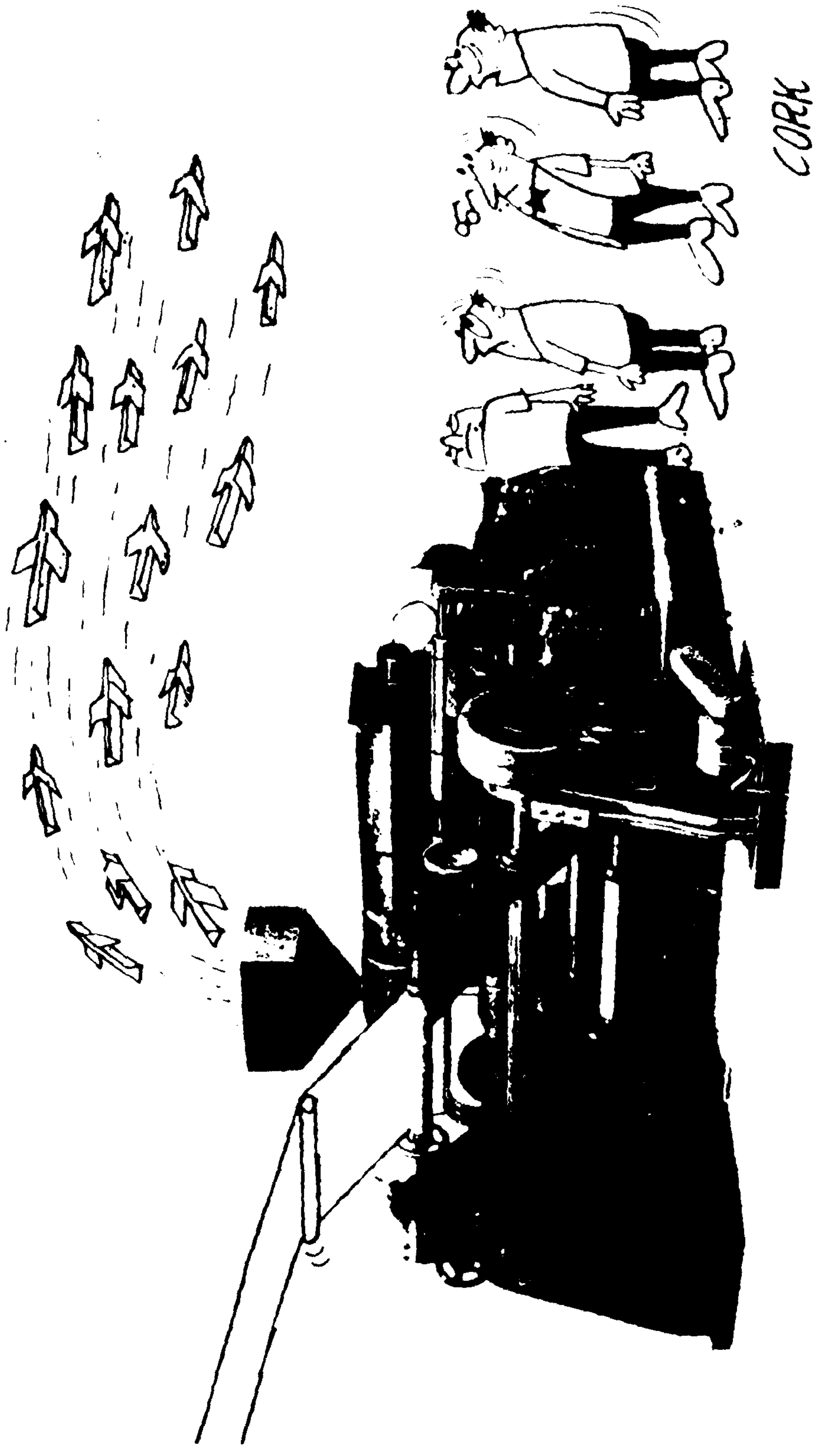
GROUND CLEARANCES

- MAX TAIL DOWN
- 5° ROLL
- STRUT & TIRE COMPRESSED

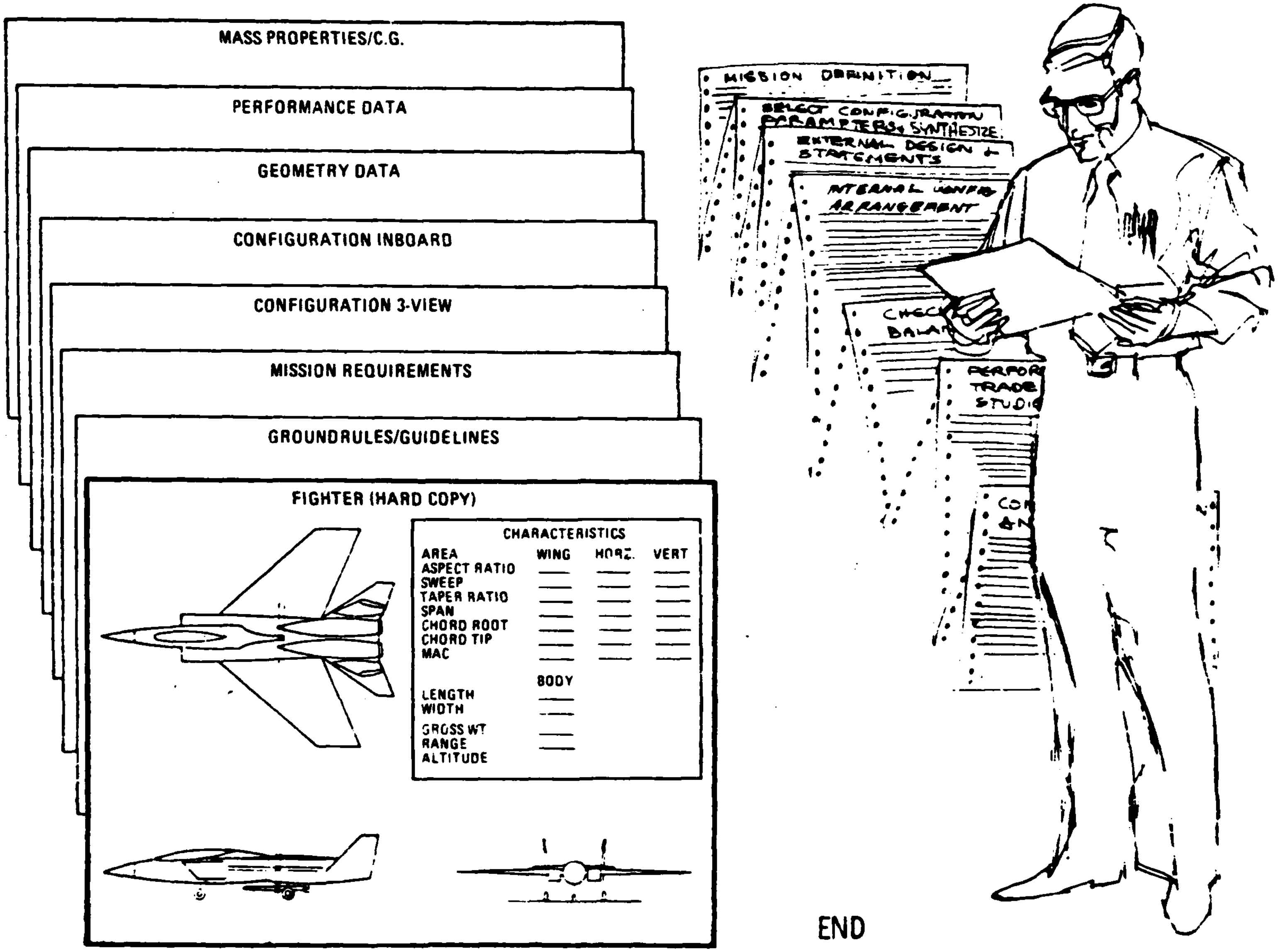




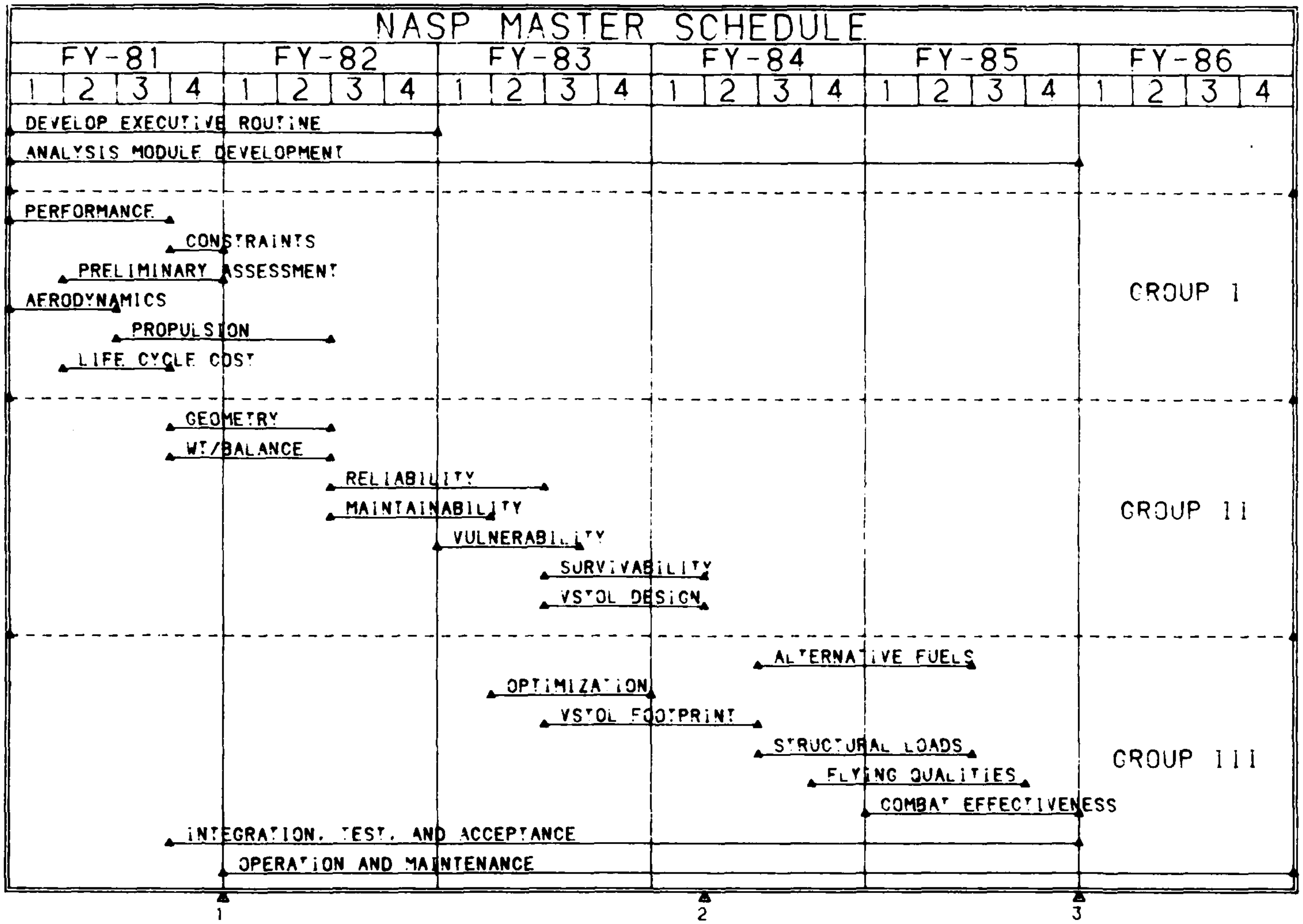
SCHEMATIC OF LIMITED-WAR ACTION



"PICK ONE"


MASS PROPERTIES/C.G.
PERFORMANCE DATA
GEOMETRY DATA
CONFIGURATION INBOARD
CONFIGURATION 3-VIEW
MISSION REQUIREMENTS
GROUNDRULES/GUIDELINES
FIGHTER (HARD COPY)
CHARACTERISTICS
WING
HORZ.
VERT
AREA
ASPECT RATIO
SWEEP
TAPER RATIO
SPAN
CHORD ROOT
CHORD TIP
MAC
BODY
LENGTH
WIDTH
GROSS WT
RANGE
ALTITUDE
MISSION DEFINITION
SELECT CONFIGURATION PARAMETERS, SYNTHESIZE
EXTERNAL DESIGN & STATEMENTS
INTERNAL CONFIG ARRANGEMENT

END

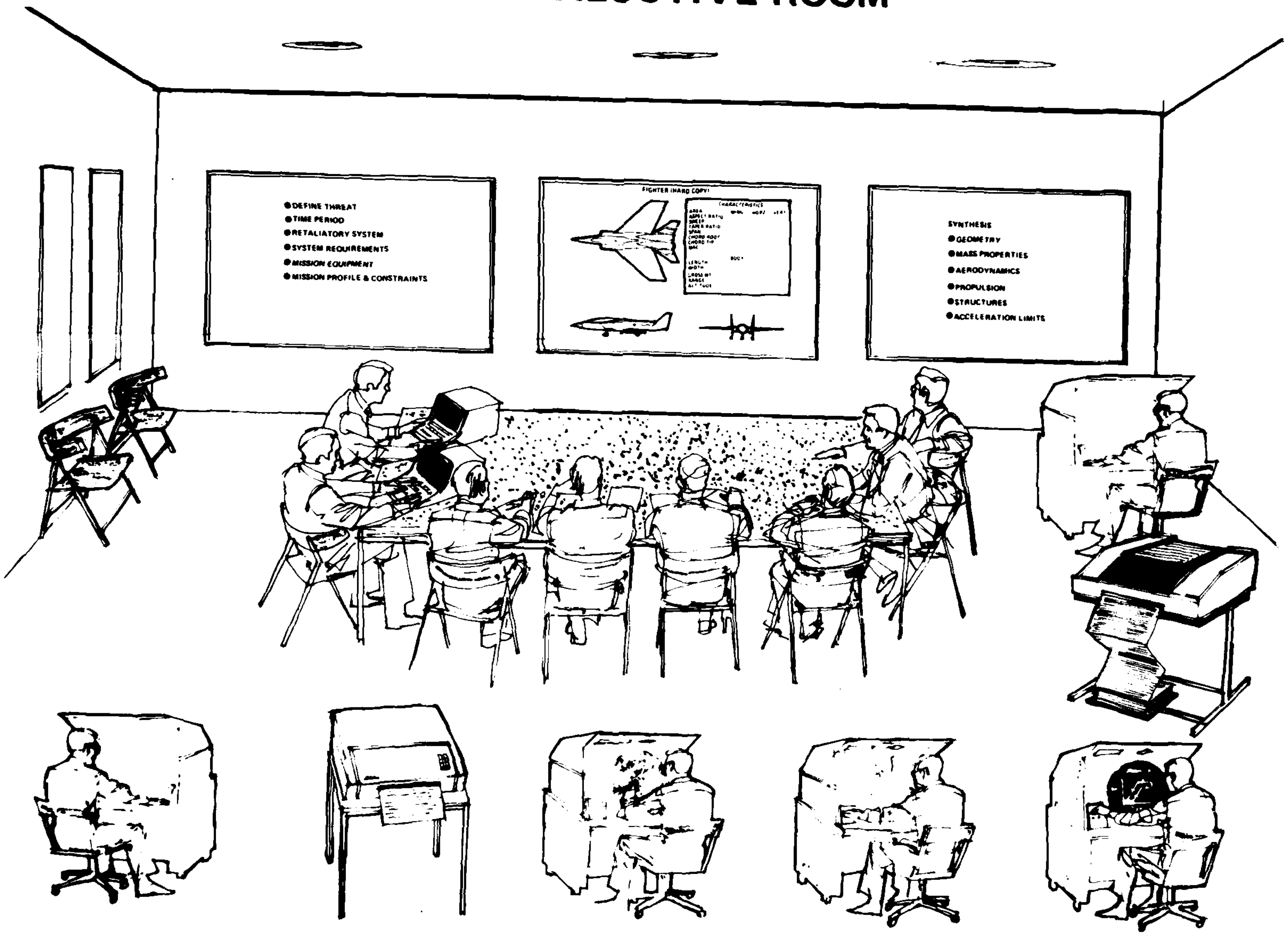


1: FIRST RELEASE. USABLE FOR ADVANCED DESIGN. THROUGHPUT PROPULSION AND WEIGHT DATA.
2: SECOND RELEASE. CAPABILITY FOR DESIGN OPTIMIZATION.
3: THIRD RELEASE. PROGRAM COMPLETE.

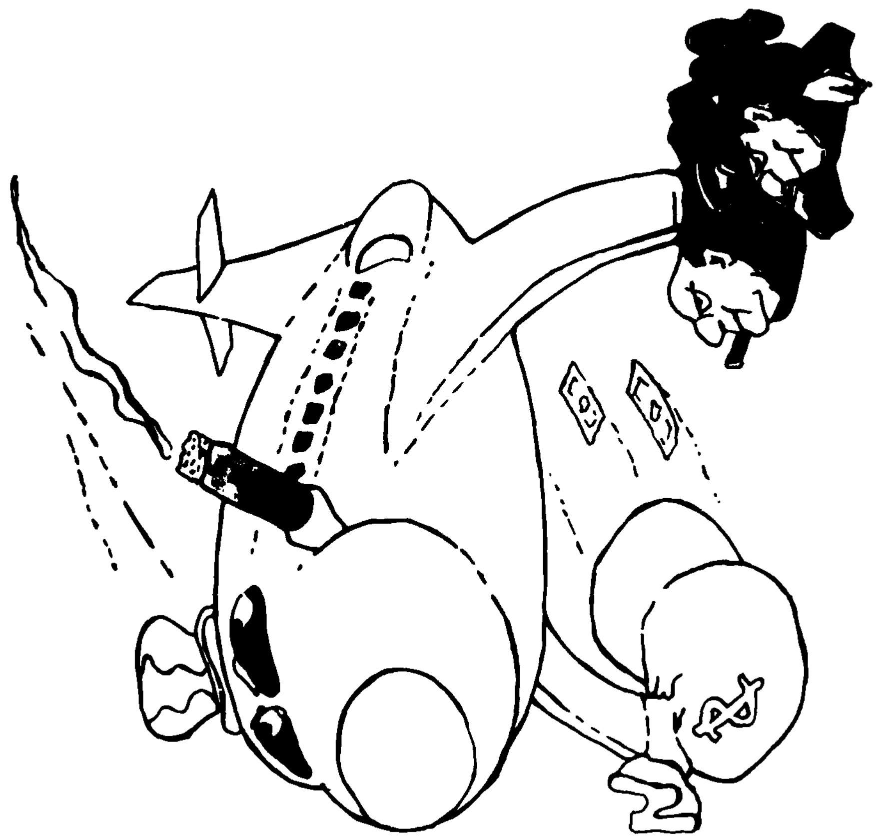
2-APR-81


BASELINE

EXECUTIVE ROOM



06033CVD5866



COMPUTER GRAPHICS IN THE ADVANCED CONFIGURATION DESIGN & ANALYSIS PROCESS

T.J. Weir
Northrop Aircraft Division
Hawthorne, California

COMPUTER GRAPHICS IN THE ADVANCED CONFIGURATION DESIGN & ANALYSIS PROCESS

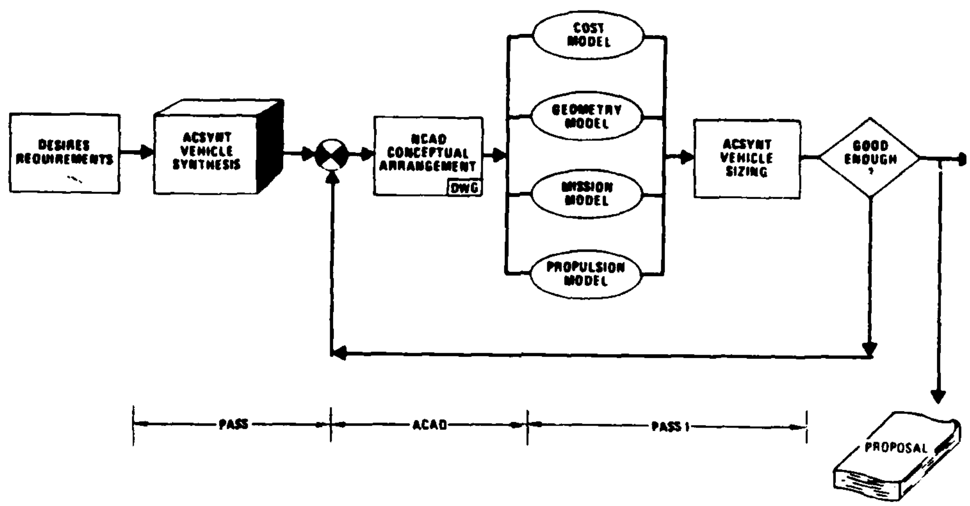
T.J. Weir
Northrop Aircraft Division
Hawthorne, California

To meet the rigorous constraints imposed upon supersonic aircraft, the conceptual designer must mold and shape the entire configuration by iteratively locating critical components such as the engine, fuel bays, guns, radar, and crew stations and then drawing accurate, smooth body control lines and many section cuts to assure adequate clearances and a proper cross-sectional area distribution for minimum wave drag. Assuring proper aircraft balance, minimum weight, cockpit visibility, and landing gear placement for rotation clearance are but a few of the design considerations.

Manually drawn, smooth, accurate shapes are very time-consuming, cumbersome to construct and analyze, and painstaking to iterate. Through computer graphics' use of modular library components, rapid curve fit routines, and automatic section construction, the designer is given much relief from the rote task of mechanical construction and afforded more time to address the critical design integration functions. This paper presents the Northrop hardware/software system, Advanced Configuration Analysis and Design (ACAD) system, discusses techniques involved and concludes with some applications to aircraft survivability as inputs to signature and vulnerability models.

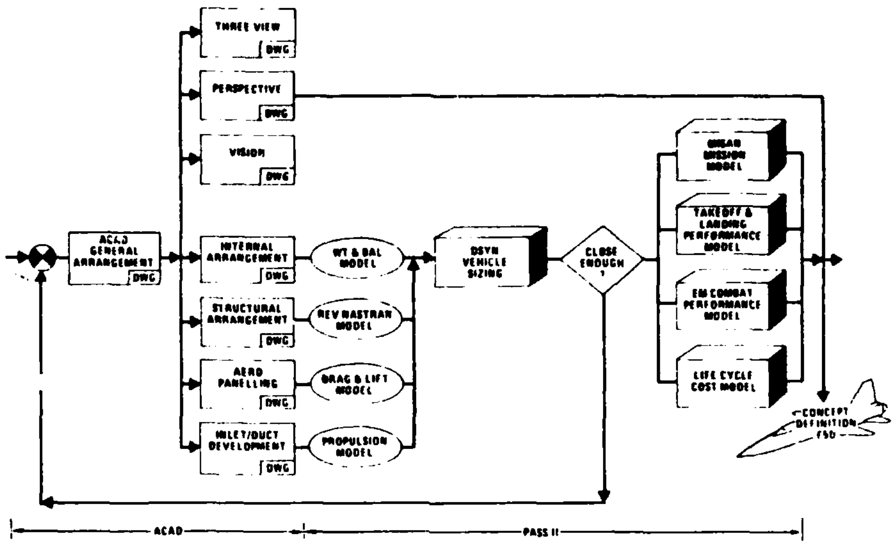
The problem-solving process is much like the chicken and egg dilemma: which came first? Whether a solution is synthesized to meet a problem or whether the problem is analyzed to produce a solution is a somewhat moot question. For the purpose of this paper, let me define the synthesis process as starting with a blank piece of paper and developing a solution to a problem. This is contrasted with the analysis process wherein the analyst is given a baseline approach, and proceeds to analyze its capability to solve the problem. Many computer design packages tend to start with the analysis loop, where mission requirements, etc., are fed into one end of the computer and a "synthesized" configuration comes out the other end. The ACAD process starts with a vehicle synthesis or design and then proceeds to the analysis.

THE ACAD PROCESS
CONCEPTUAL DESIGN LEVEL I



The design process as defined by ACAD covers the first two phases or levels of the Aircraft Design process; conceptual design, and preliminary design. The design process starts with a vehicle synthesis or design and then proceeds to the analysis. This is not the only approach to the problem, rather, it is the way that the conceptual design process has evolved at Northrop and represents a logical extension of the design approach using new tools.

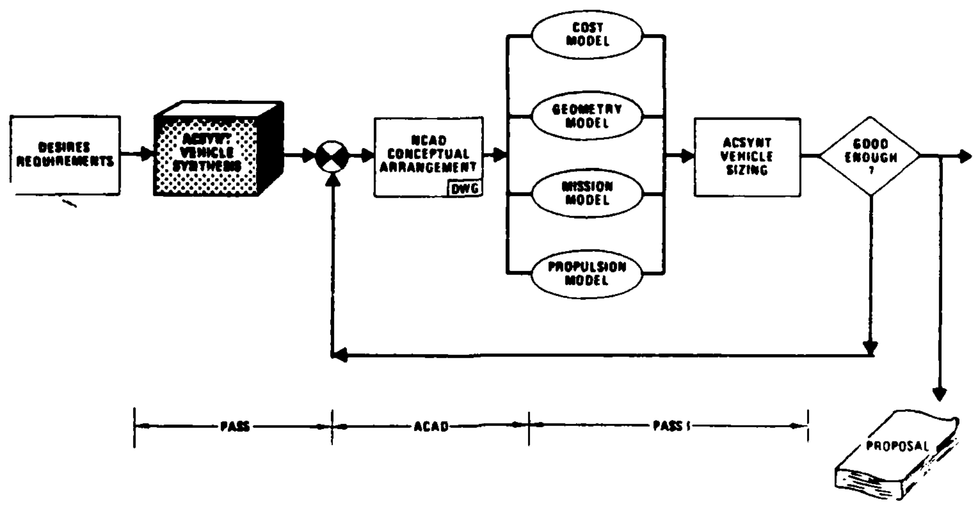
THE ACAD PROCESS
PRELIMINARY DESIGN LEVEL II & III



The preliminary design phase consists of a more detailed definition of the vehicle followed by a multi-disciplined examination and analysis to determine the validity of the design. This process requires significant data generation, computation, and design iterations as the design evolves. By the use of computer graphics and computer generated data sets, this process is made more rapid and accurate.

2170-1 (8-78)

THE ACAD PROCESS
CONCEPTUAL DESIGN LEVEL I



The first step in the Design Process is to synthesize a concept that satisfies specified requirements such as: mission radius, payload, takeoff and landing distances, operating altitude and speed, and combat turn and acceleration performance. The ACSYNT program presented here is a vehicle synthesis program developed by NASA and now being utilized by Northrop. This program is very flexible in that it can compute widely differing vehicles from large transports to small fighters. By the specification of certain constraints many different solutions may be obtained from the same set of requirements.

ACSYNT INPUT DATA

```
                         INITIAL WEIGHTS INPUT DATA
                         ACSYNT MODULE NUMBER 6
                         MODULE VERSION 4-78
AIRCRAFT TYPE:  FIGHTER
TITLE:             TEST AIRCRAFT WEIGHTS (DEFAULT)

CONTROL OPTIONS

   IPRINT =  1   IGRAPH =  1   ITAIL  =  6   KERROR =  0
   IDFLT  =  0   IOSLIO =  6   KWING  =  1   KBODY  =  1
   K1     = 1.00 K2     = 1.00 K3     =  1.0 K4     =  1.9
   K5     = 1.00 K6     = 1.00 APMACH = 0.0  MAXIT  =  1
   K8     = 0.0  KP1    = 0.0  KP2    = 0.0
   FR     = 1.50 TECHG  = 1.00 WGTO   =    28000.
   STRESS =    36000.          DENS   =  0.096     FLIFTF =0.0
   TECHI  =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
 SLOPE(1) =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
 SLOPE(9) =  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00

INITIAL ESTIMATES
 IF CODE = 1, WEIGHT IS FIXED
```

QUANTITY		VALUE	CODE	QUANTITY		VALUE	CODE
WAF	=	7824.	0	WAIRC	=	260.	1
WAPU	=	0.	0	WAMMUN	=	200.	1
WARM	=	30.	1	WMAG	=	0.	0
WBBI	=	6.	6	WBODY	=	2821.	1
WCANO	=	0.	0	WCARGO	=	0.	0
WCREW	=	215.	1	WE	=	9632.	1
WELT	=	916.	1	WEP	=	645.	1
WETANK	=	0.	0	WFEQ	=	3599.	0
WFS	=	695.	1	WCA	=	730.	0
WGEAR	=	78.	0	WHDP	=	1290.	1
WHT	=	370.	1	WINST	=	120.	1
WLG	=	730.	1	WMISS	=	0.	0
WNA	=	261.	0	WPA	=	0.	0
WPASS	=	0.	0	WPL	=	3104.	0
WPS	=	3599.	0	WSC	=	645.	1
WTSUM	=	26006.	1	WVT	=	141.	1
WWING	=	1806.	1	WBOMB	=	960.	1
WENVP	=	0.	0	WPIV	=	0.	0
WLIFTF	=	0.	0				

* * * BEGIN VEHICLE CONVERGENCE

This represents a print of input data which is used to define a solution vehicle. The ACSYNT program is set-up to run with logical defaults where all inputs are not specified. As few as sixteen inputs have been used to derive solutions. These solutions have shown good agreement with more defined solutions which require over a thousand inputs.

ACSYNT MISSION DATA

TRAJECTORY INPUT

TIMTO1 = 5.0	MENDUR = 1.	NCRUSE = 2	IPLOT = 0
TIMTO2 = 1.0	QMAX = 700.	IPSIZE =-2	HMINP = 0.
FRFURE = 0.0	XDESC = 80.0	IPSTO1 = 5	HMAXP = 55000.
DESLF = 8.00	WKFUEL = 1.000	IPSTO2 = 2	DELHP = 4000.
ULTLF =12.00	CRMACH = 1.600	IBREG = 0	SMMINP = 0.050
RANGE = 250.	WKLAND = 0.570	IENDUR = 0	SMMAXP = 1.600
WFUEL = 8336.	FLFAC = 0.600	IPRINT = 0	DELMP = 0.100
WFEXT = 0.	DECEL = 0.250	KERROR = 2	WCOMSP = 0.04
WFTRAP = 200.	NLEGCL = 0	NLEGCR = 0	NLEGLO = 0
FWGMAX = 1.200	TOL = 0.001	MILCOM = 0	NMISS = 1

MISSION 1

PHASE	MACH START	MACH END	ALT START	ALT END	HORIZ DIST	TIME	NO. TURNS	VIND WKFUEL	IP IPRT	IX IB	IW IA
CLIMB	0.40	0.95	500.	44000.	12.6	1.6	0.0	0.0	1	-1	0
								1.000	0	0	0
CLIMB	1.60	1.60	44000.	50000.	51.1	4.3	0.0	0.0	1	-1	0
								1.000	0	0	0
CRUISE	1.60	1.60	50000.	50000.	-1.0	0.0	0.0	0.0	4	1	0
								1.000	0	0	0
COMBAT	0.90	0.90	30000.	30000.	0.0	2.9	4.0	0.0	1	0	0
								1.000	0	0	0
COMBAT	1.20	1.20	30000.	30000.	0.0	1.6	2.0	0.0	1	0	0
								1.000	0	1	0
CRUISE	0.90	0.90	50000.	52000.	-1.0	0.0	0.0	0.0	4	1	0
								1.000	0	0	0
LOITER	0.40	0.90	0.	0.	0.0	22.0	0.0	0.0	4	0	0
								1.000	0	0	0

CALLING MODULE NUMBER 3

The mission can be described simply or in great detail depending on requirements and/or desires. Presented here is a sample imput of a typical fighter mission.

ACSYNT OUTPUT DATA

SUMMARY — ACSYNT OUTPUT — NASA, AMES RESEARCH CENTER

TEST AIRCRAFT CONVERGENCE (COPES) 10/01/80

GENERAL		FUSELAGE			WING	HTAIL	VTAIL
WG	30799.	LENGTH	47.5	AREA	400.0	141.7	33.5
W/S	76.9	DIAMETER	6.0	WETTED AREA	529.4	163.0	27.0
T/W	1.05	VOLUME	994.7	SPAN	29.1	20.6	6.5
N(Z) ULT	12.0	WETTED AREA	742.6	L.E. SWEEP	58.0	58.0	48.5
CREW	1.	FINENESS RATIO	7.9	C/4 SWEEP	50.5	44.3	35.0
PASSENGERS	0.			ASPECT RATIO	2.1	3.0	1.3
				TAPER RATIO	0.1	0.2	0.3

ENGINE		WEIGHTS	W	%		WING	HTAIL	VTAIL
					T/C ROOT	0.04	0.04	0.04
					T/C TIP	0.04	0.04	0.04
NUMBER	2.				ROOT CHORD	25.0	11.3	8.0
LENGTH	14.2	STRUCT.	5961.	19.4	TIP CHORD	2.5	2.4	2.4
DIAM.	2.9	PROPUL.	6327.	20.6	M.A. CHORD	16.8	7.8	5.7
WEIGHT	3069.1	FIX. EQ.	4708.	15.3	LOC. OF L.E.	17.5	36.2	39.[illegible]
TSLS	16100.	FUEL	12230.	39.8				
SFCSLS	2.04	PAYLOAD	1533.	5.0				

MISSION SUMMARY

PHASE	MACH	ALT	FUEL	TIME	DIST	L/D	THRUST	SFC	V
TAKEOFF		500.	673.	6.0	3494.9				
CLIMB	0.90	44000.	1765.	2.5	18.3	4.1	10295.8	2.2	223.8
CLIMB	1.54	50000.	133.	0.2	3.5	2.6	13205.2	2.1	402.4
CRUISE	1.60	51590.	3517.	12.0	189.1	2.7	9923.5	1.7	408.4
COMBAT	0.90	30000.	1648.	2.9	25.6	5.6	10698.8	2.2	357.0
COMBAT	1.20	30000.	1236.	1.6	18.8	4.0	21636.1	2.1	634.7
CRUISE	0.90	36593.	1146.	23.8	205.0	6.5	3109.0	0.9	134.3
LOITER	0.40	0.	1062.	22.0	97.0	8.0	2604.4	2.6	237.0
LANDING					8634.9				

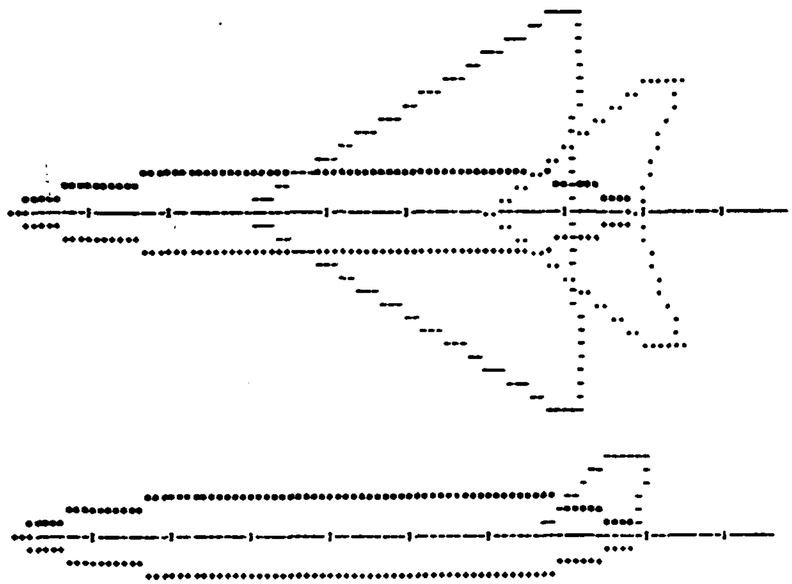
BLOCK TIME = 1.004 HR
BLOCK RANGE = 551.4 NM

COMBAT PHASES

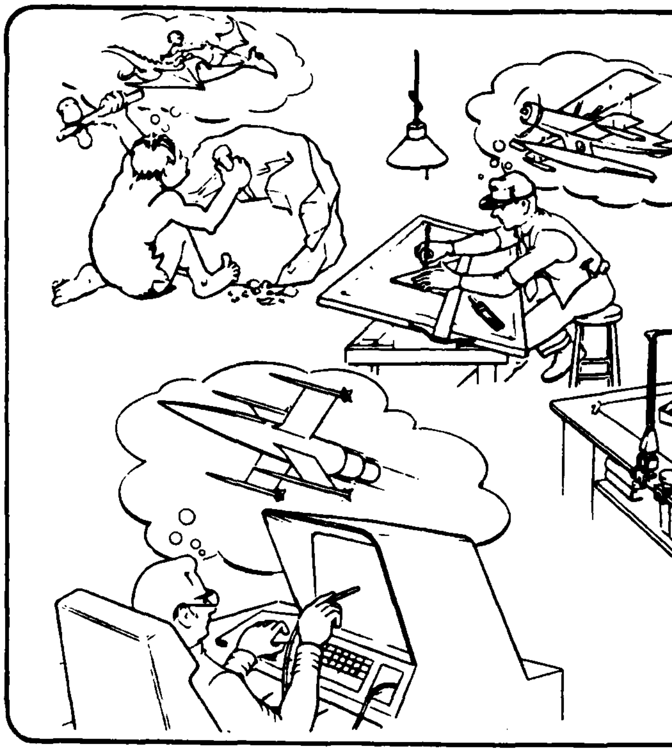
MACH	ALT	PSIG	NZS	CLS	CDS	ALS	NZI	PSI	CLI	CDI	ALI	CBE
0.90	30000.	468.	3.3	0.549	0.1106	10.9	7.5	-5282.	1.229	1.1049	40.0	81371.
1.20	30000.	402.	3.9	0.340	0.0448	5.6	9.0	-1645.	0.705	0.2079	12.4	39613.

The output of the ACSYNT program is always described by a complete set of data independent of the number of input data. All the physical dimension data, weights, engine size and cycle, wing geometry, and fuel quantities are presented. This does not represent an optimized solution but a point solution that meets mission requirements based on the input data. The optimum solution is obtained by a numerical regression, optimizing the design variables to derive the minimum size vehicle.

ACSYNT OUTPUT VEHICLE



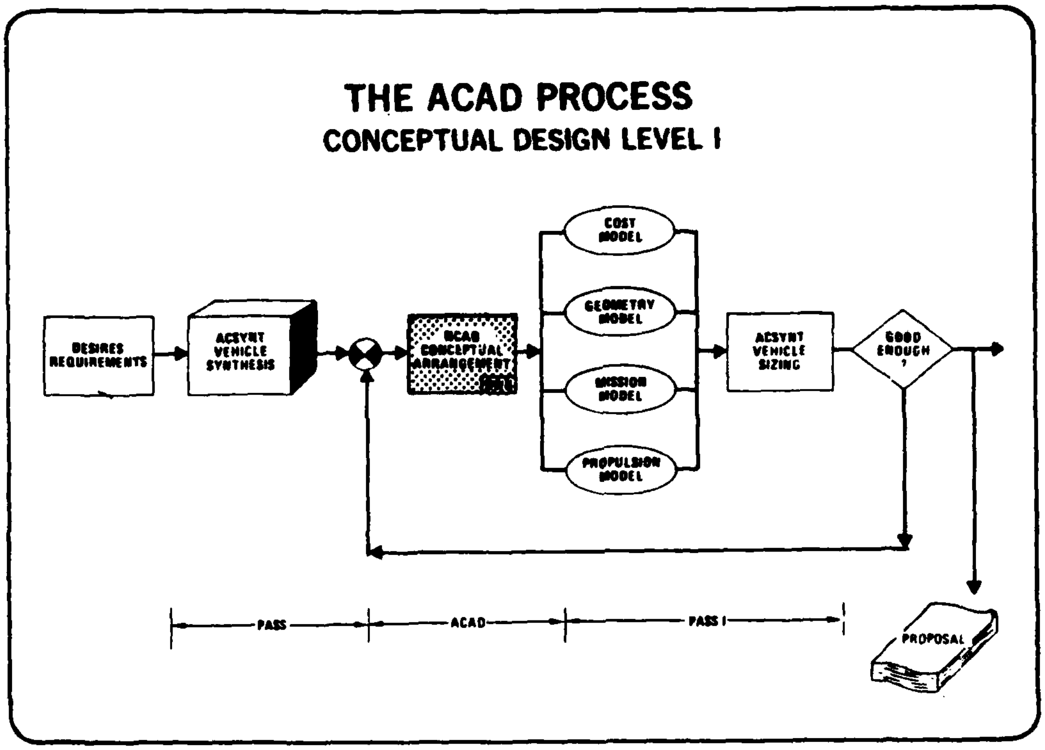
Along with the tabulated output data, ACSYNT also likes to draw a picture of its solution. Being limited to very basic tools, i.e., stars, dots, and X's, it tries its best to construct a two-view drawing. Note, no engine inlets or canopy.



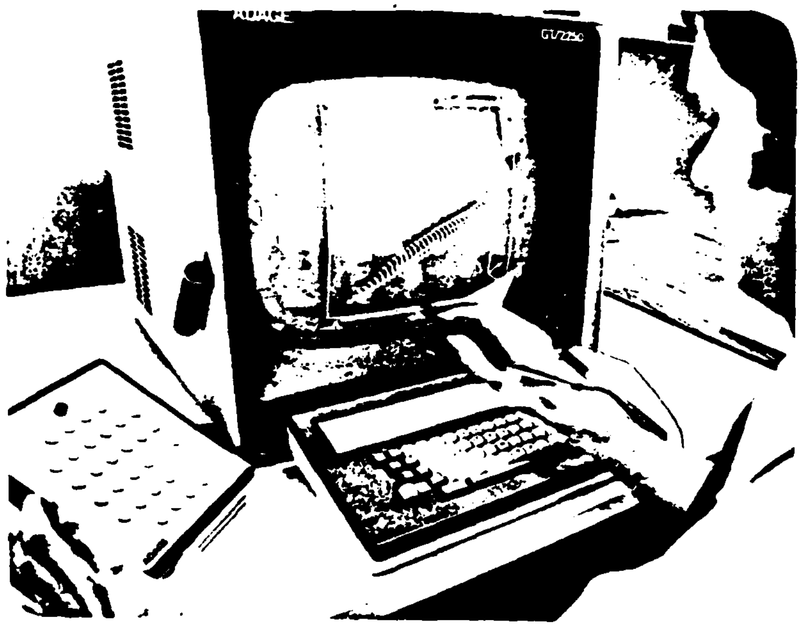
EVOLUTION OF THE DESIGN PROCESS

Since the very beginning, man has tried to express his dreams in some graphic manner. The earliest man used the crudest of tools for drawing and calculations were limited to counting on his toes. As time passed, the dreams became more sophisticated and the tools necessary to communicate these dreams developed from T squares to drafting machines and computing tools evolved from slide rules to programmable hand-held calculators.

Tomorrow's airplane will be defined with tomorrow's computer-aided drawing and analytical tools. One such hardware/software system, the Advanced Configuration Analysis and Design (ACAD) system, is currently being used at Northrop.



The conceptual arrangement is the designer's chance to stylize the concept and hopefully make it a workable design. The design tool utilized here is the NCAD three dimensional graphics system which creates a three dimensional drawing of the vehicle and defines it with surface patches. The resulting drawing represents a concept which has been packaged and refined to show cockpit, inlets, landing gear, weapons, subsystems, and fuel tankage.

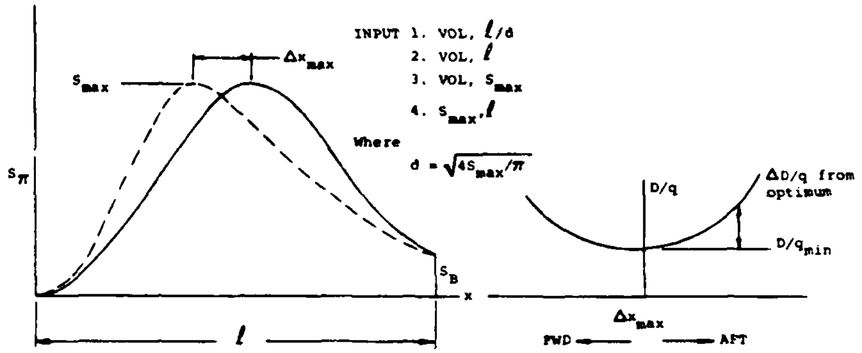


The ACAD system consists of an ADAGE GT/2250 display console or equivalent, with related display control units and long line adapters, a large IBM system 370 computer with its related disk, drum and tape storage systems, a Universal Drafting Machine Orthomat plotter system, and a Versatec or Gould electrostatic plotter system.

The ACAD designer uses the designers' console as an input/output device for graphics operation. Two of these consoles are connected to a display control unit which accepts data and cues the data for transmission to the computer system in another complex.

The console provides high-speed exchange of data and visual display between the computer and the designer. The console displays tables, graphs, charts, drawings, and alphanumeric data on the face of a cathode-ray tube. The function keyboard, alphanumeric keyboard and the light pen supply the means for entry and change of displayed information.

OPTIMUM WAVE DRAG BODY OF REVOLUTION



$$D/q(\ell/2)^2_{min} = -\frac{1}{2\pi}\int_{-1}^{1}\int_{-1}^{1} S''(x)S''(\xi)\log_e\left|x-\xi\right|dx +$$

$$\frac{S^1(1)}{\pi}\int_{-1}^{1} S''(x)\log_e(1-x)\,dx - \frac{1}{2\pi}\left[S^1(1)\right]^2\log_e\frac{\beta}{2}\sqrt{\frac{S(1)}{\pi}}$$

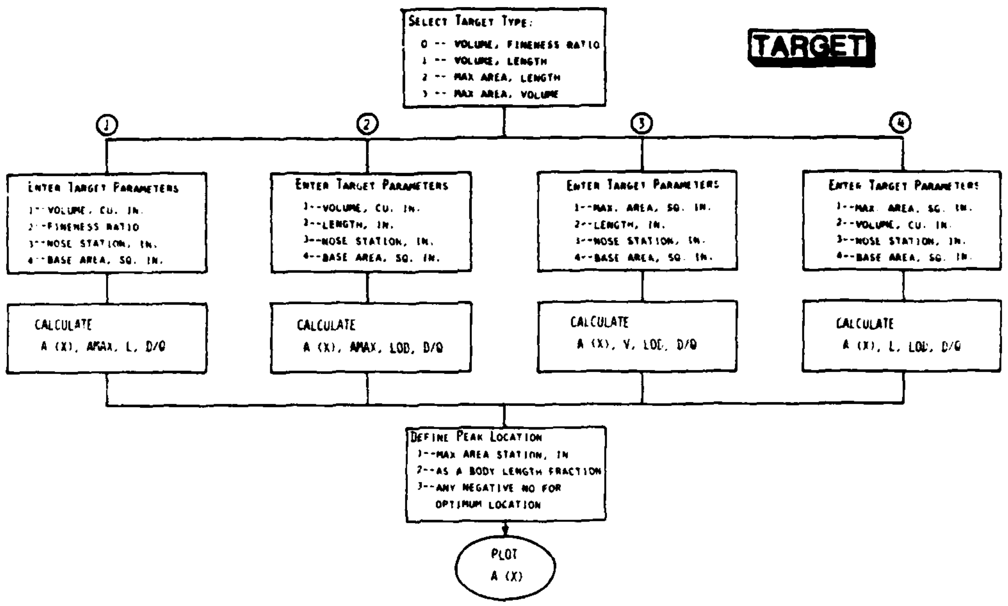
Given a body of revolution in a supersonic flow field, its wave drag is a function of the distribution of the volume in the free stream direction. Using the methods of Adams*, an optimum distribution of volume for minimum wave drag can be calculated. In the equation shown in the figure, the variables of volume, fineness ratio (length divided by diameter), and maximum cross sectional area can be combined with two as dependent variables and the third being the independent variable. It is then possible to calculate an optimum distribution of volume.

However, it not always possible for the designer to place the maximum cross-sectional area of the aircraft at the point for minimum drag. Consequently, it is necessary to assess the drag impact of skewing the distribution for a new peak location and consequently calculating a new target area distribution for this location. When the net volume of the airplane has been determined, the designer uses the Adams method to produce an overall target area distribution as shown above.

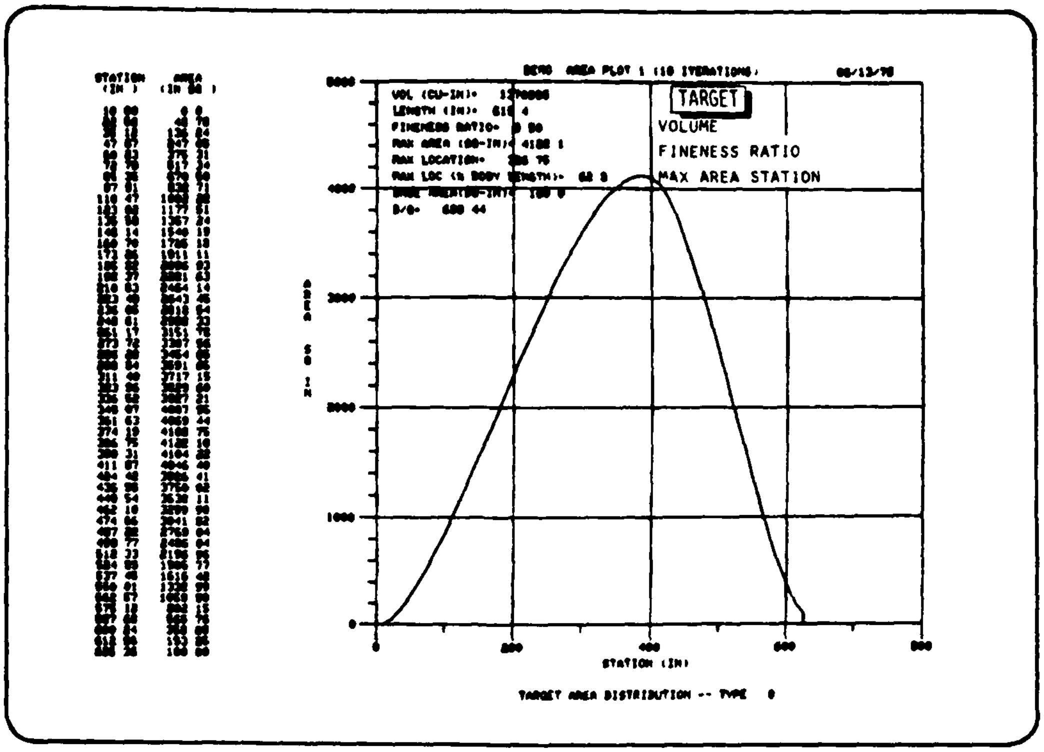
---

*Adams, Mac C., "Determination of Shapes of Boattail Bodies of Revolution for Minimum Wave Drag, NACA TN 2550, August 21, 1951.

LOGIC FLOW DIAGRAM

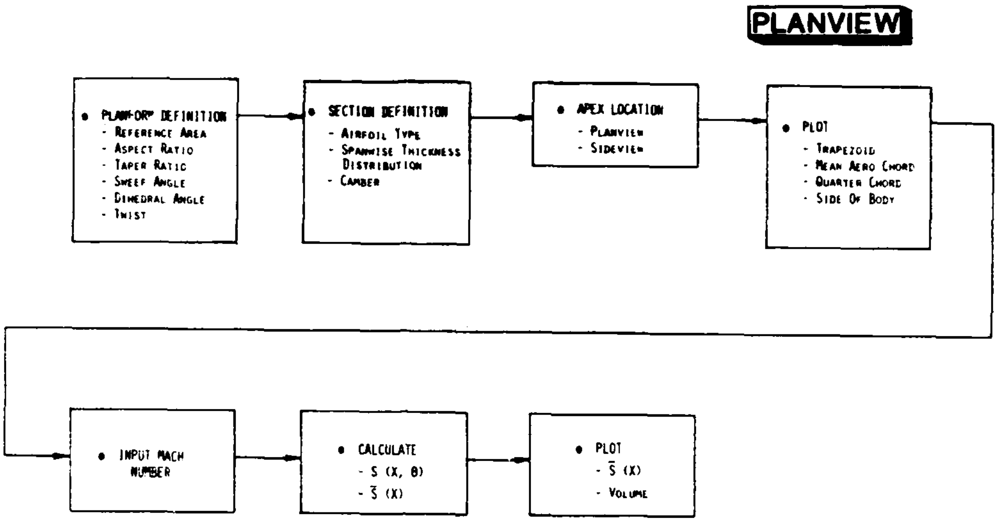


The target program provides the designer with a total aircraft target area distribution from parameters of volume, fineness ratio, overall length, and maximum cross-sectional area. Only two of these parameters are needed to develop an optimum shape with the other two parameters taken as dependent variables. The target types correspond approximately to the Adams target types. After the user selects the target type and enters the two basic parameters, with a further notation of the nose station and base area, the target area distribution may be selected either with the peak located at an optimum location, at a specific location, or as a fraction of the body length. With any of these options, a relative drag value is calculated and included on the face of the plot.



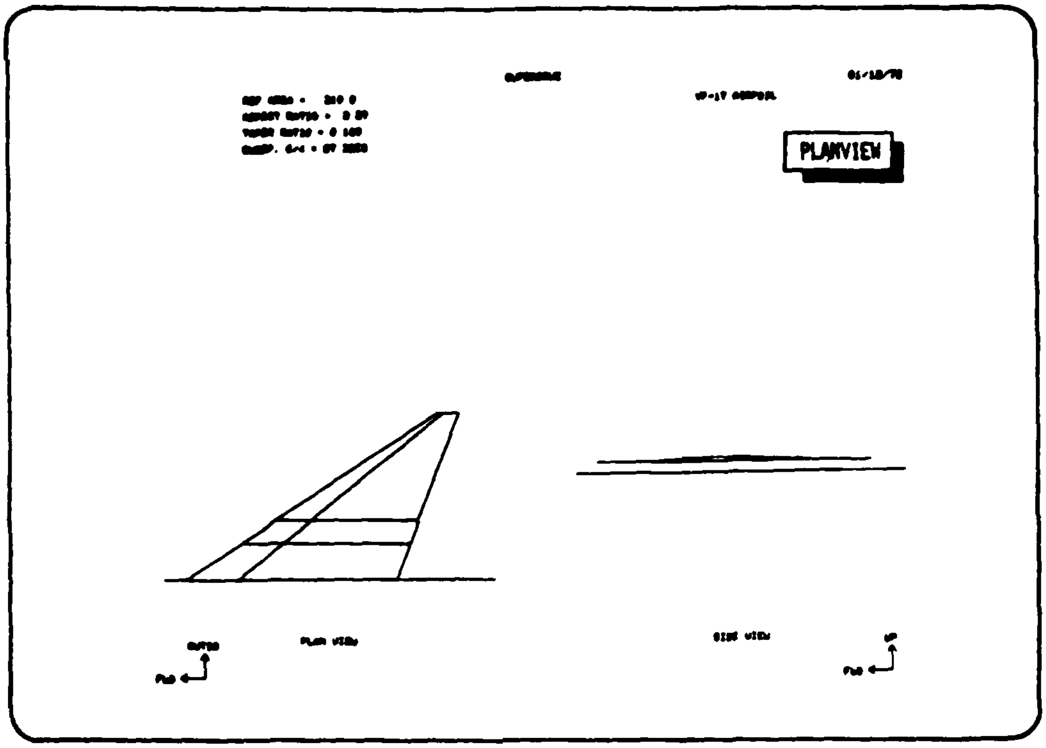
This is a typical output of the target program where volume, fineness ratio, and specific station for the maximum area were utilized as program inputs. The resulting target area distribution has a value of $\frac{D}{q}$ = 699 square inches. For convenience, the data are plotted digitally to the left of the plot.

LOGIC FLOW DIAGRAM



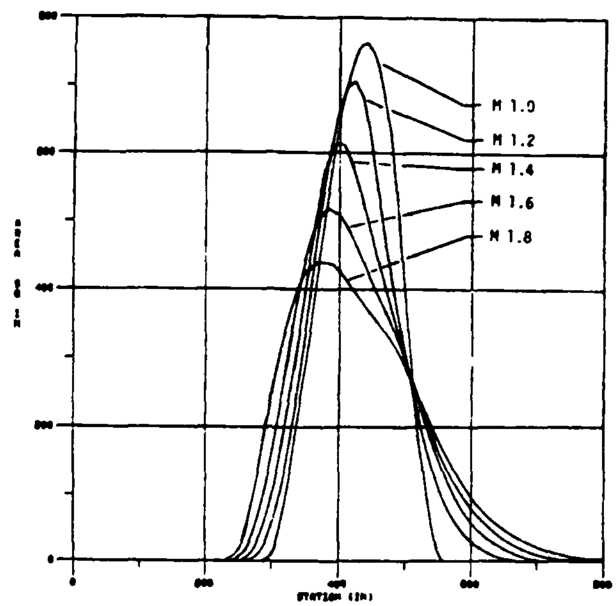
The planview program allows the designer to calculate wing and empennage planview drawings as a simple entity by using standard geometric parameters. Equivalent cross-sectional area distributions are also calculated.

This diagram summarizes the input parameters required for the planview routines to define wing and empennage planforms, develop section definition, and calculate the equivalent area distribution of the exposed surface as a function of the design Mach number.

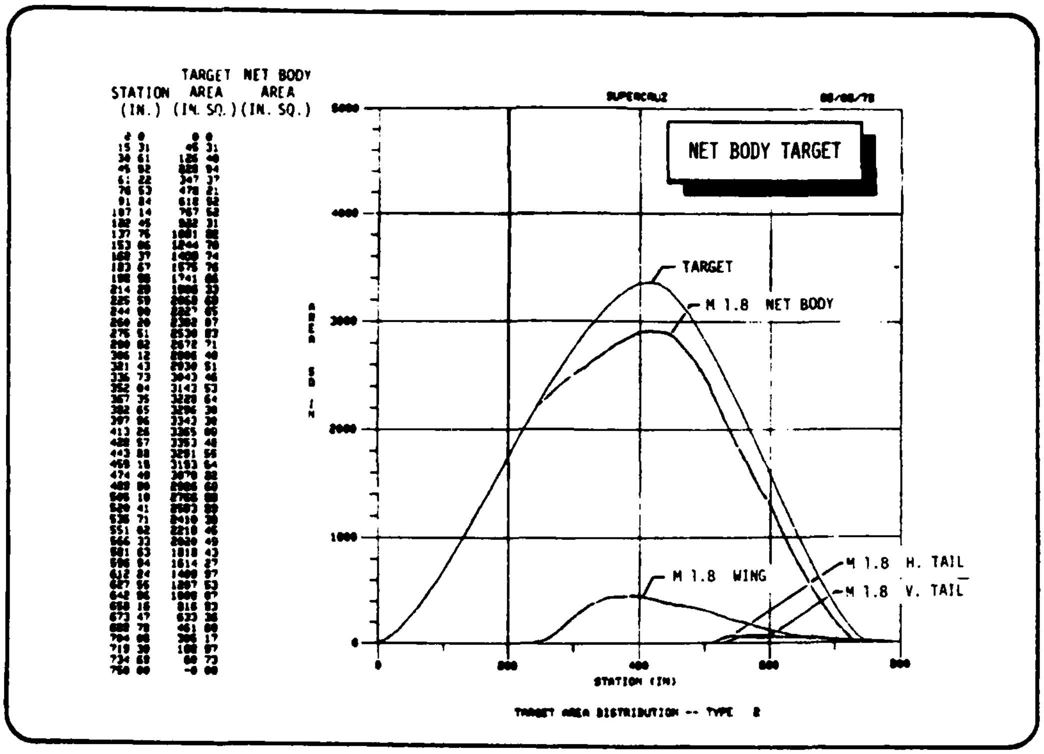


This is a sample printout of the planview program which enables the designer to readily visualize the wing in both plan and sideview. For convenience, the major geometric parameters are summarized automatically on the drawing.

MACH EFFECTS ON WING AREA DISTRIBUTION



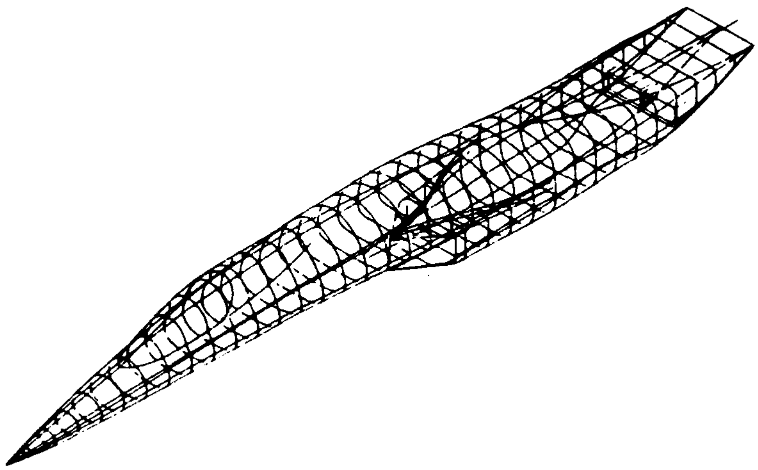
The angle of the cutting plane is equal to $\sin^{-1}(1/M)$. Thus, with increasing Mach number the cutting planes are passed through the wing and empennage at increasing angles. The effect of this increase in Mach number is to "smear" the area distribution as shown in the figure above. Note that the volume is constant under all of these curves. Since the target body area distribution will be greatly affected by the particular wing area distribution, which is subtracted, it is important for the designer to estalish at the outset which design Mach number will be used to optimize the body.



The net body target program is a simple summation program which subtracts the wing and empennage equivalent area distributions from the overall target to produce a net body target.

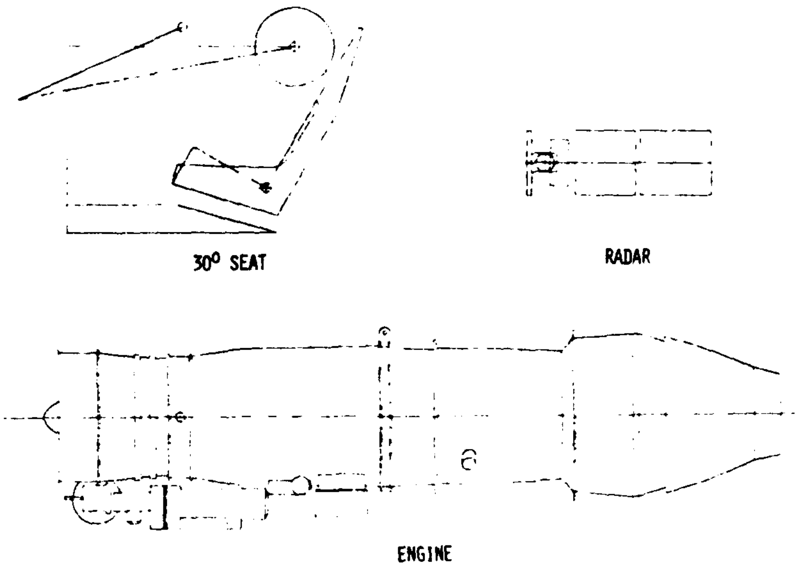
The resulting net body target is shown here for a design Mach number of 1.8. This module is in the development stage and when completed will present the designer with the display shown plus the rapid capability to shift wings and empennage fore and aft, and will aslo present the body equivalent diameter.

BODY DEVELOPMENT



The following charts will sequentially depict the development of the body shown in this figure. The drawing of the control lines, construction of the sections, and calculation of the cross-sectional area distribution is presented.

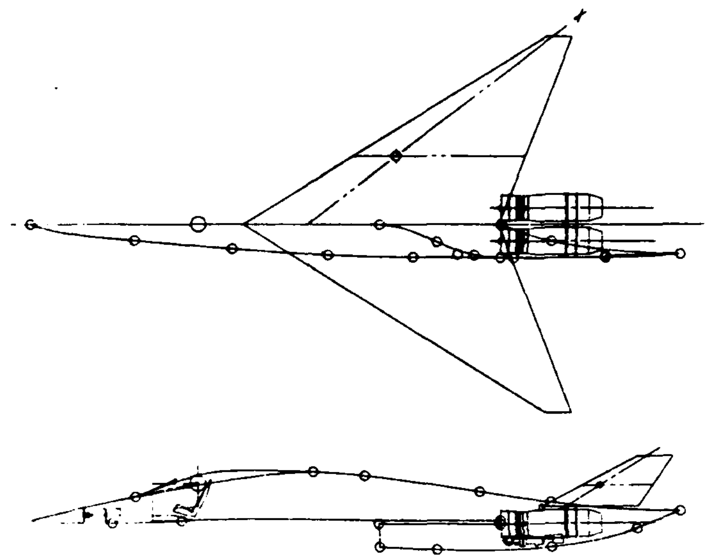
STANDARD LIBRARY EXAMPLES



Within the user's CADAM drawing files, or stored within libraries, are several baseline components such as radars, crew stations, and engines. The components shown in this picture do not represent actual hardware options, but rather generic concepts depicting the scope of detail necessary for the designer to begin the process. The crew station above shows the essential elements of seat back angle, helmet clearance, and eye and seat reference points.

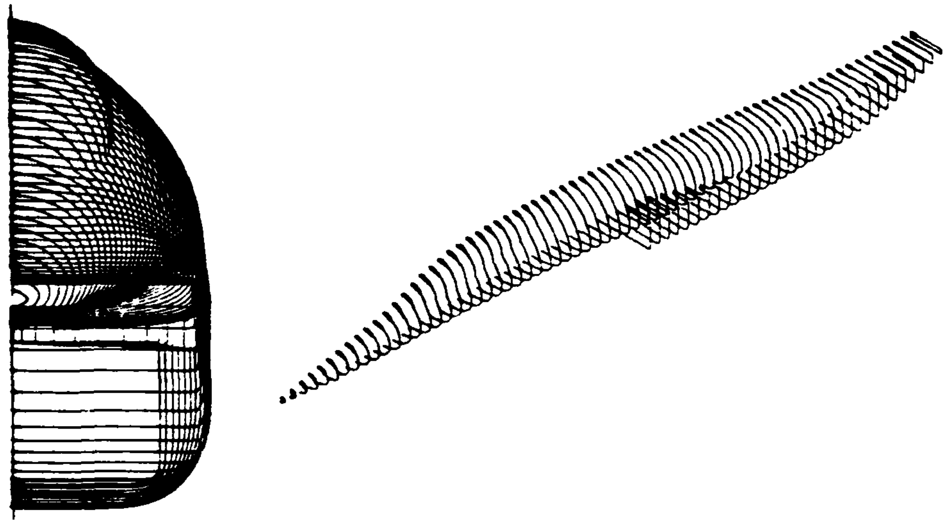
It should be noted that CADAM enables the designer to scale independently in both X and Y; for example, engines scale differently in diameter and length as a function of thrust. Using the CADAM capability, an engine can be rapidly derived through this scaling option.

CONTROL LINES DEVELOPMENT



Once the overall configuration length has been determined, the system modules may be "hung" on the screen in any location and orientation selected by the designer within these limits. He then assures adequate clearance as shown by the data points circled for reference on this drawing. Once satisfied with this placement, the designer then uses the CADAM functions of splines, conics, lines, and circles to draw the control lines. These control lines can be readily displayed, and changed, with the stroke of a light pen. This procedure of defining the external control lines of the airplane continues until adequate definition exists for the construction of three-dimensional shapes.

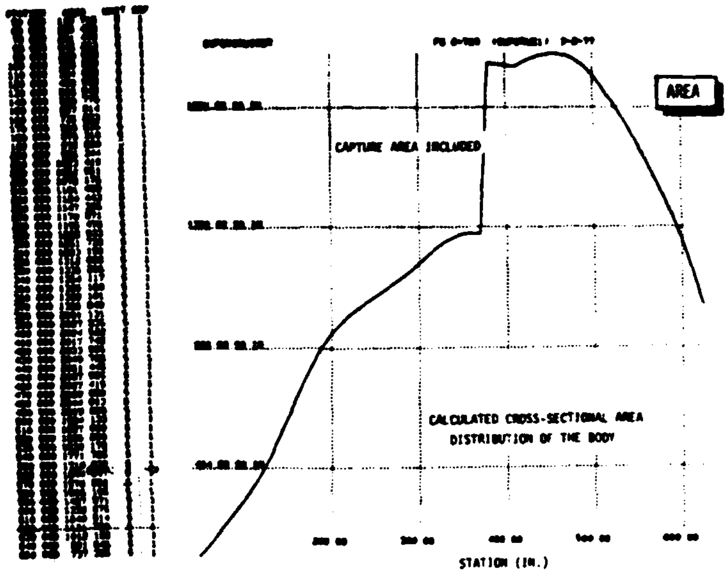
COMPLETE LOFTED BODY



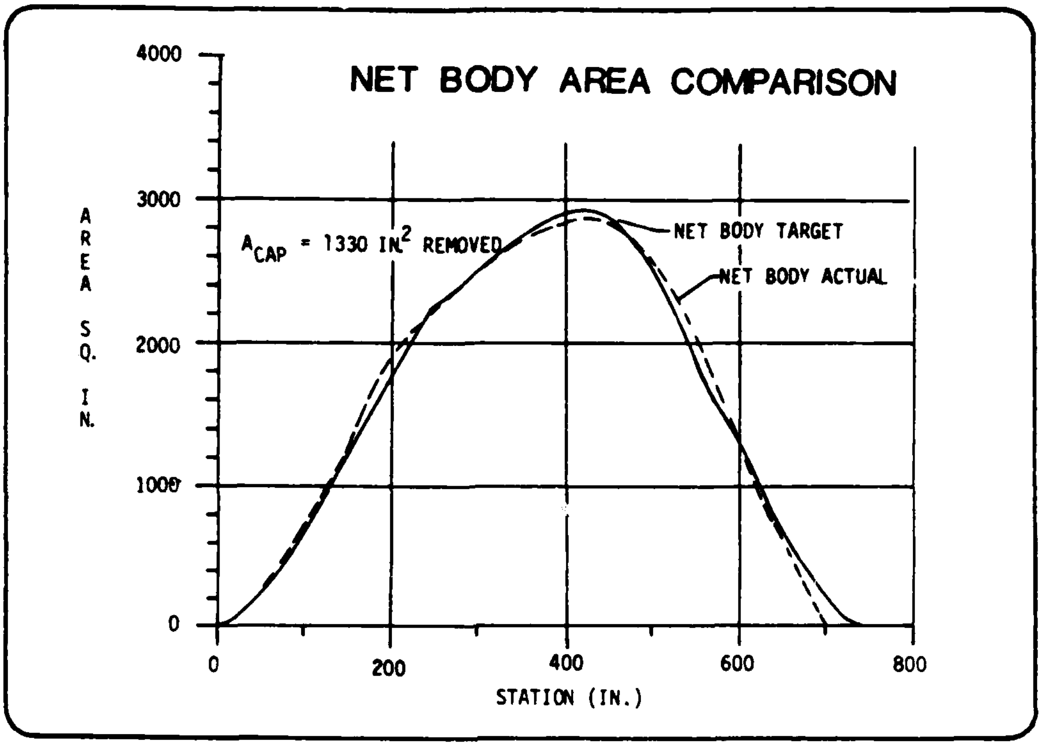
The figure above demonstrates the desirability of large main frame models for configuration control. In this view, seventy complex sections were generated on the screen without filling the model or the buffer. The ability to use this dense spacing of sections for control of asthetics is well illustrated.

Display flexibility permits viewing the sections on one or both sides, either head-on or in isometric view.

ACTUAL NET BODY AREA DISTRIBUTION

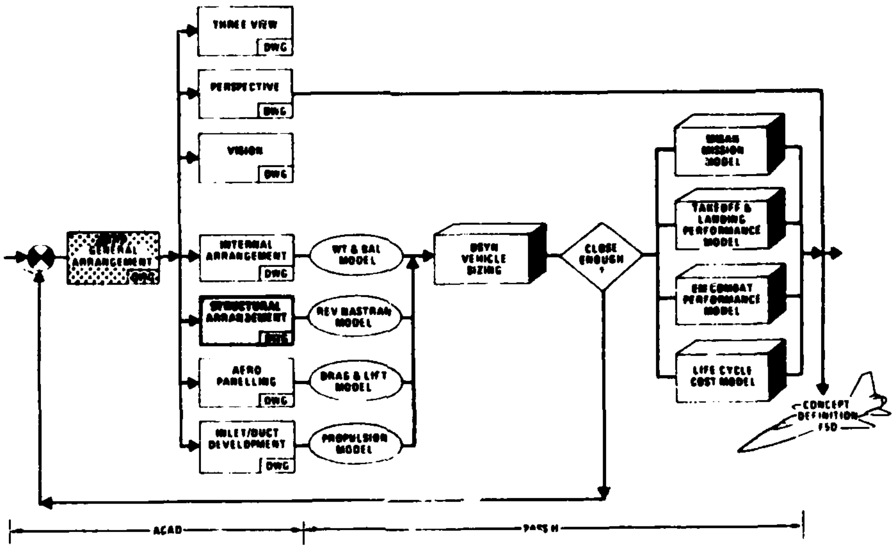


When the designer is satisfied that the body lines are properly faired and that adequate clearance is available for all of the major subsystems, he may then enter the AREA subroutine and calculate the actual cross-sectional area distribution as a function of body station. This example shows both the plotted area distribution and the digital values displayed simultaneously on the screen. The discontinuity between stations 370 and 380 occurs at the inlet and represents the inlet capture area.



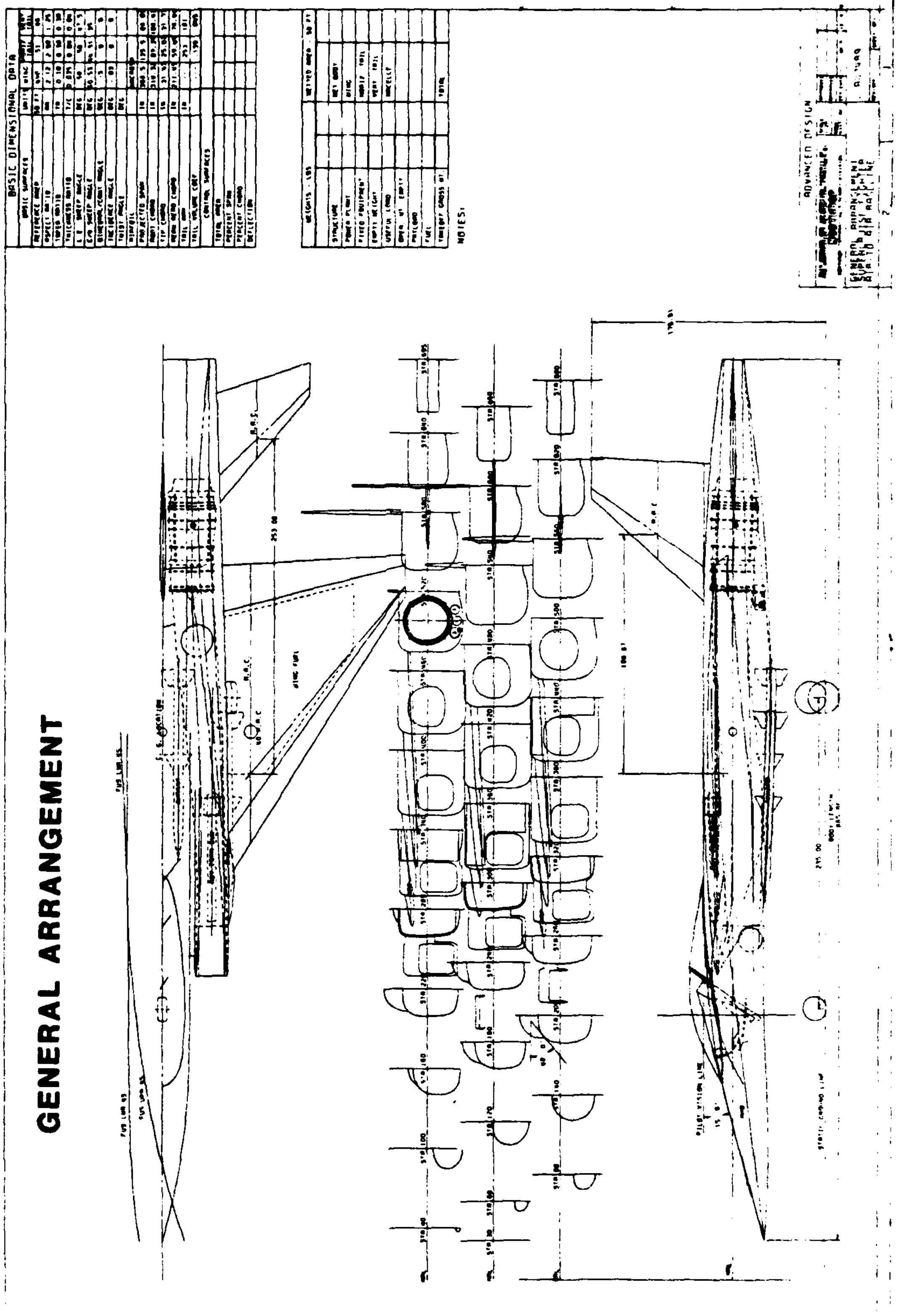
With the engine inlet capture area removed, the body actual area distribution can then be compared with the net body target area distribution shown on page 28. At this point, the designer has the option of revising the control lines and/or the target area distribution as appropriate.

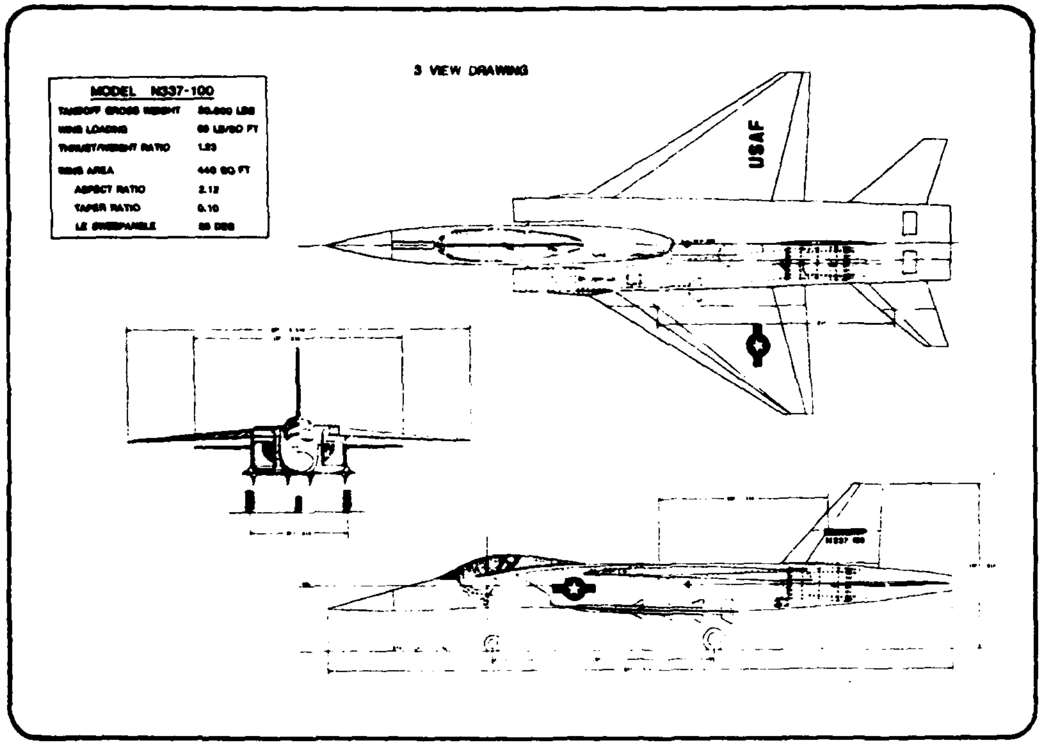
THE ACAD PROCESS
PRELIMINARY DESIGN LEVEL II & III



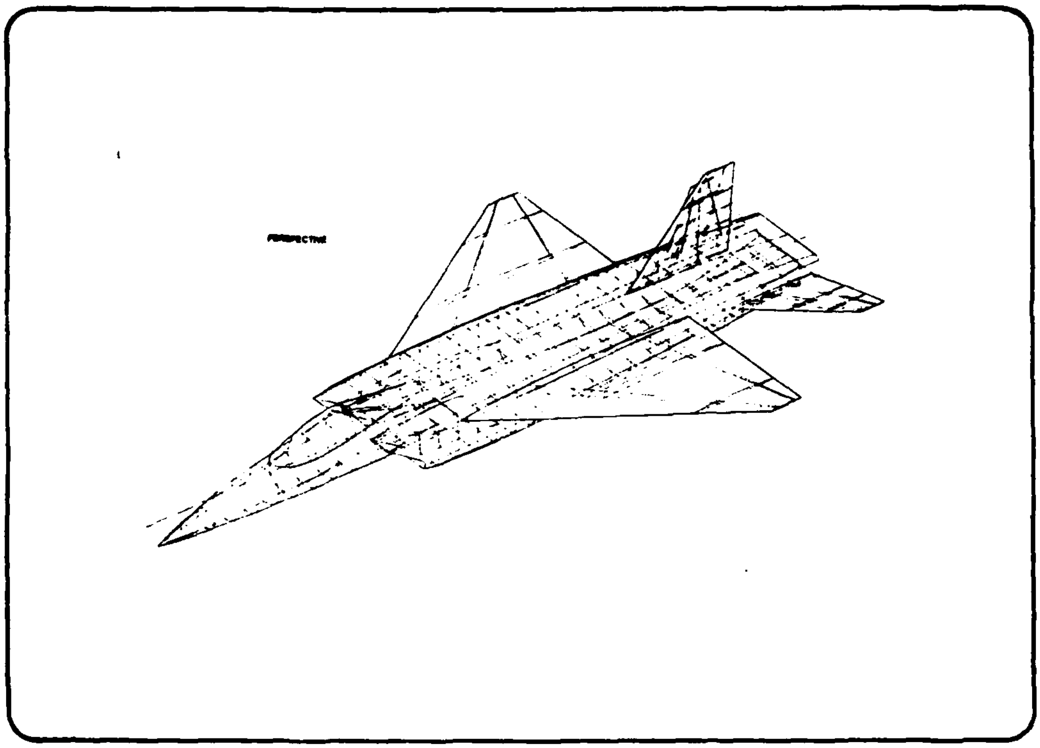
The General Arrangement Drawing becomes the principal vehicle definition and the collector of all design inputs in the preliminary design phase. This level of the design process represents a more detailed and complete effort as is reflected by the number of supporting drawings. These drawings must be of sufficient detail to assure that all systems fit, there is structural integrity, and that the external lines are smooth and continuous.

2170-1 (8-78)


GENERAL ARRANGEMENT
BASIC DIMENSIONAL DATA
NOTES:
ADVANCED DESIGN

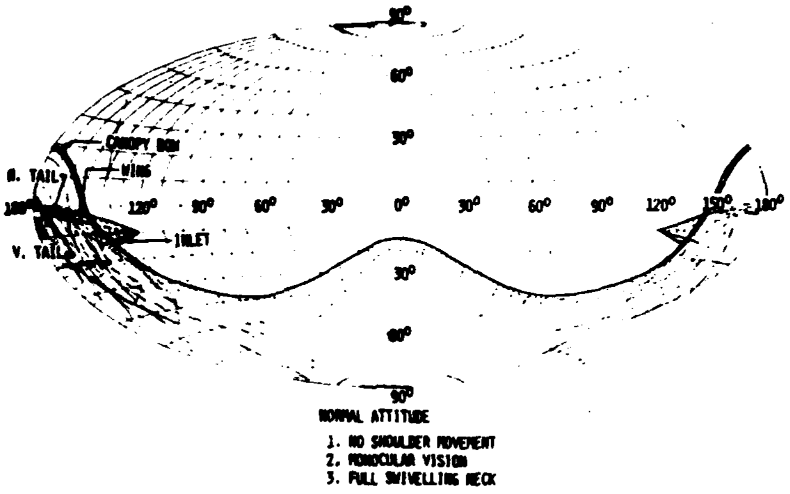


An example of a report-quality 3-view drawing produced from the ACAD general arrangement drawing. This drawing can be produced and revised rapidly utilizing ACAD.

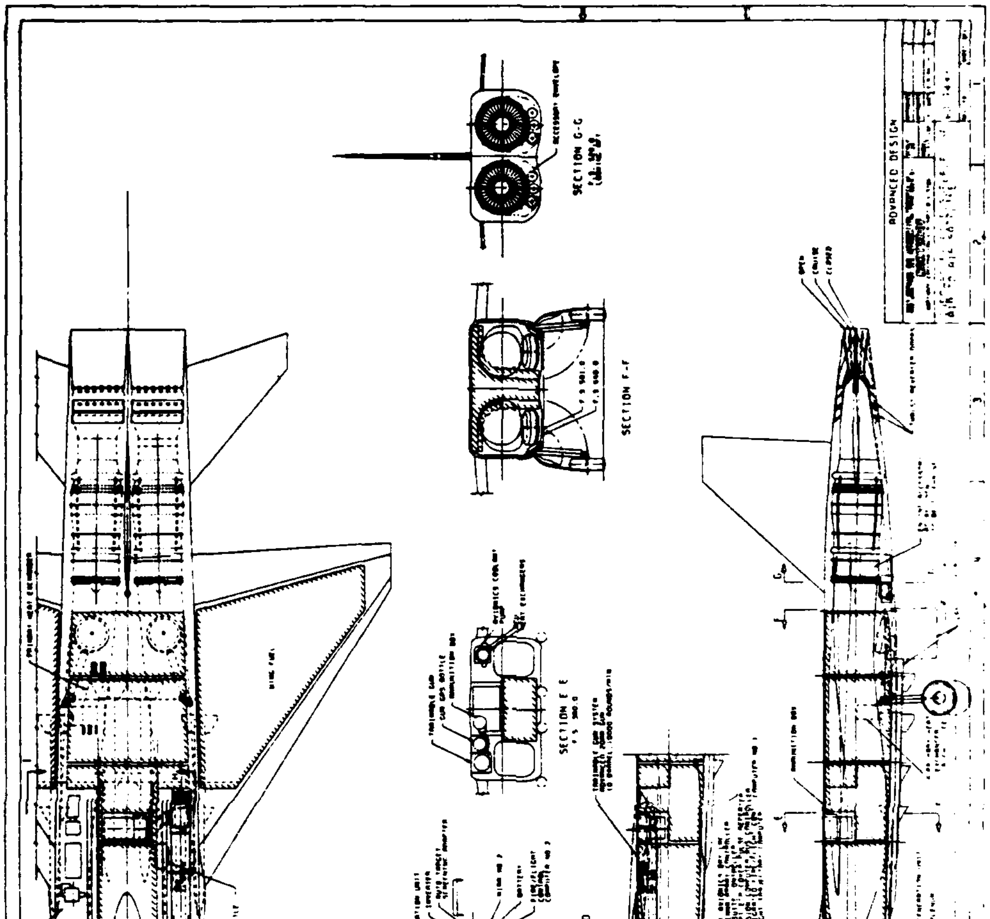


Perspective drawings can also be produced for visualization and artist renderings. *Any angle of rotation or eye location can be used.*

AITOFF'S EQUAL AREA



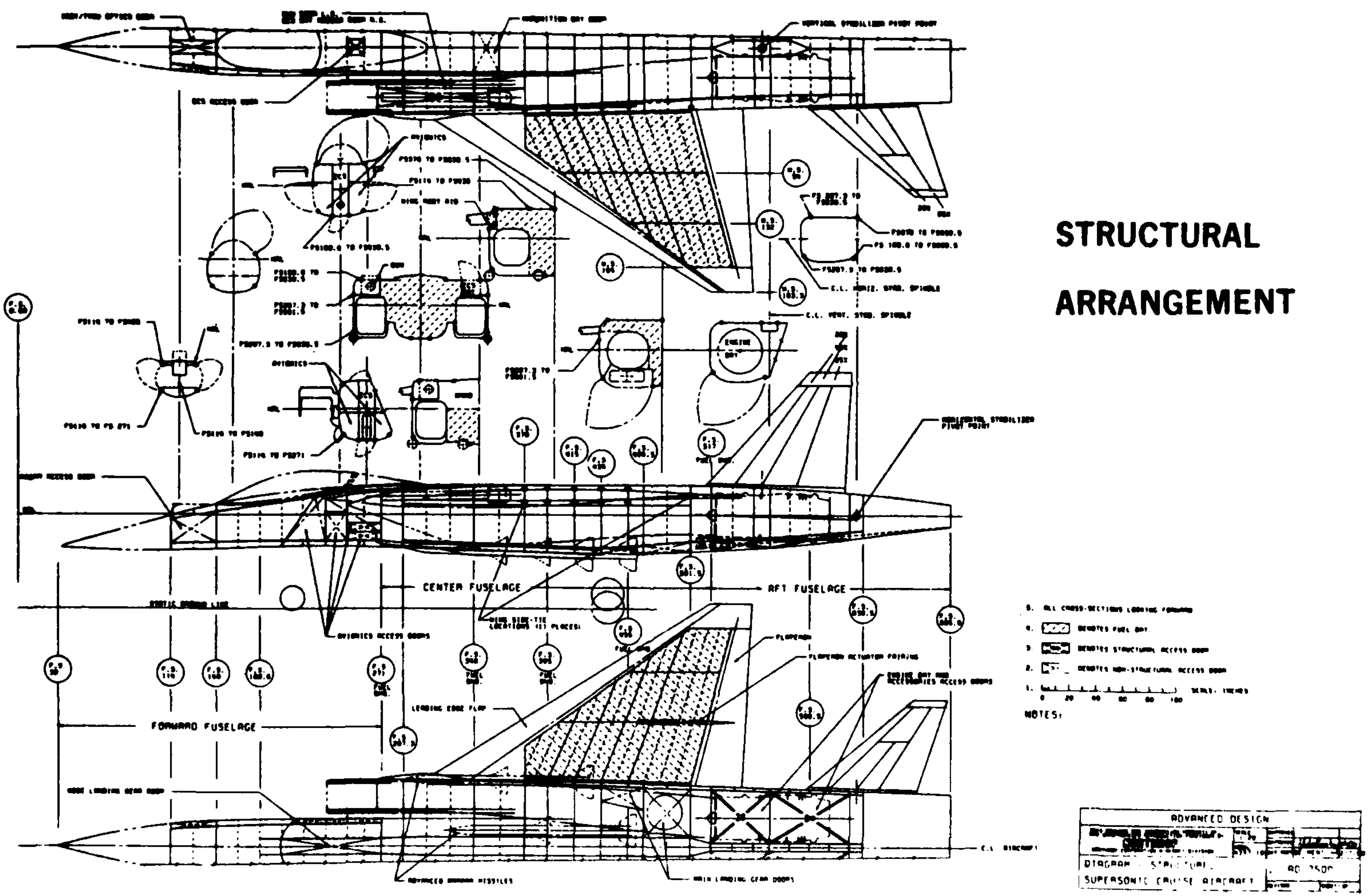
Aitoff's vision plots are a standard representation to show the pilot's vision from his position in the cockpit. This type of plot used to take days to generate by hand, but now with computer graphics can be accomplished within minutes.

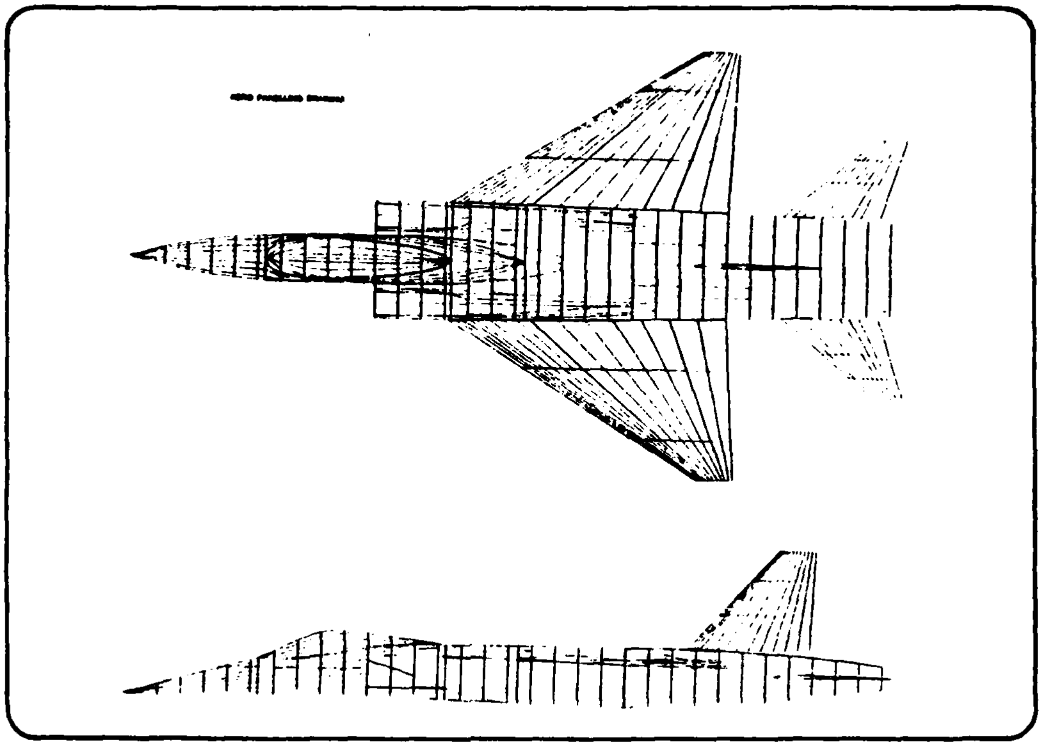


INBOARD PROFILE

STRUCTURAL

ARRANGEMENT





Aero paneling can be accomplished utilizing the geometry definition data set and the ability of CADAM to divide sections into equal segments. This data set can be easily transferred into 3-D surface patch data for utilization in automatic paneling programs.

APPLICATIONS OF COMPUTER GRAPHICS TO SURVIVABILITY MODELS

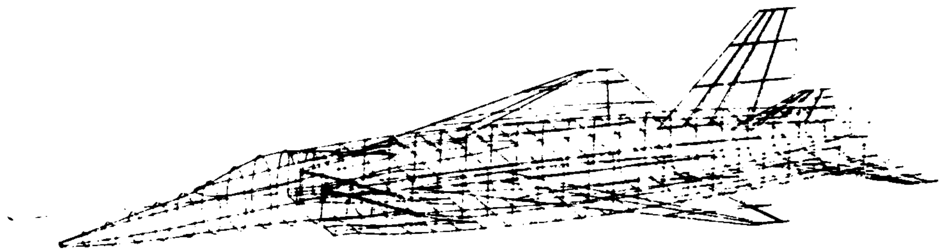
Computer graphics have opened up a new dimension in survivability assessment. Aircraft designed using computer graphics have a display capability that was not previously possible and possesses a computer data set that permits rapid analysis. Computer graphics allows the designer to inspect his concept and, if necessary, make fast and accurate iterations.

2170-1 (8-78)

INPUTS TO SIGNATURE MODELS

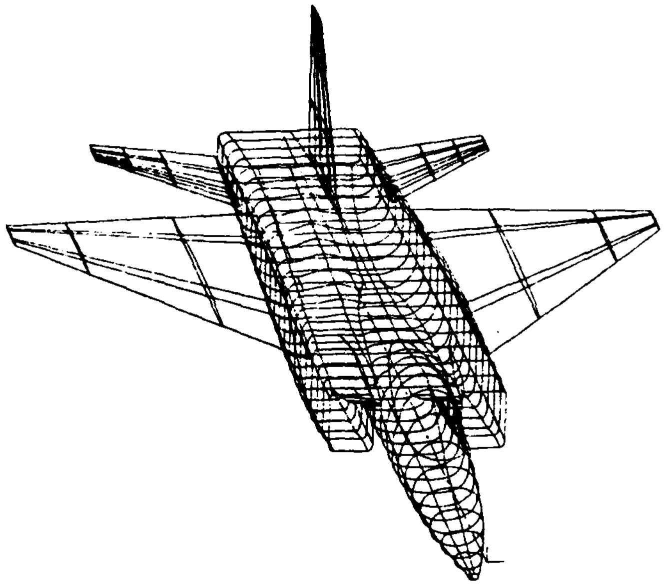
One area of survivability analysis is the ability to elude detection. There are three principal areas in the signature detection spectrum, i.e., optical, infrared, and radar.

OPTICAL



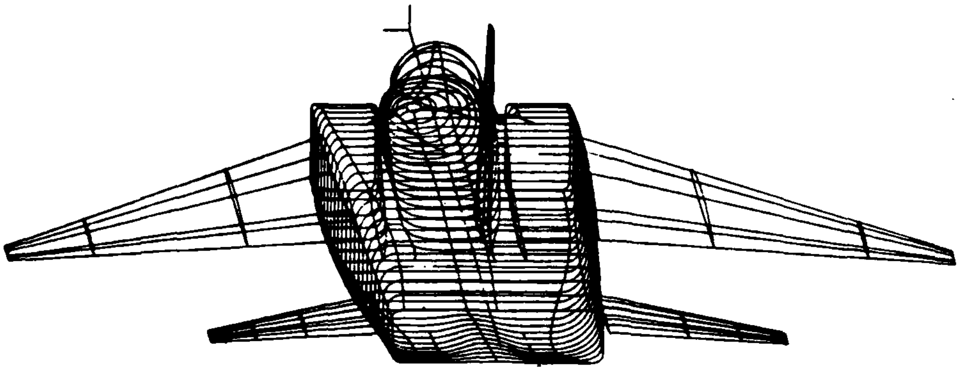
Using a computer graphics three-dimensional data set, an optical model can be generated to show the visibility of the vehicle at any altitude and/or illumination condition. This graphic system was developed by NASA and is referred to as the DICOMED system.

INFRARED



The geometric aspect of infrared modeling can easily be accomplished by graphically examining hot sections of the engine installation and determining at what aspect these areas are visible. This process is presently done manually on the display tube but could be automated to plot the temperature gradients with aspect angle.

RADAR



The electromagnetic evaluation is a combination of both the optical and the infrared technique. The NASA DICOMED system can be used to give reflectivity of edges and surfaces, while the engine face can be examined geometrically to determine the aspects it is visible.

INPUTS TO VULNERABILITY MODELS

Computer generated vulnerability drawings offer great versatility in detail of subsystem descriptions, structural elements, fragment impact points and fragment aspect angles. Almost free are the available geometric details of fuel system tank locations, fuel level variation and explosion protection system effectiveness. This all starts with the basic drawing (shown) and the subsequent inboard profile of subsystem elements. In the conceptual design phase, aerodynamic lines, structures concepts and initial subsystem arrangements provide the major input for preliminary analysis of vulnerable areas.

DAMAGE TOLERANT SYSTEMS

A - ARMOR CRITICAL COMPONENTS

B - BURY VULNERABLE COMPONENTS

C - CONCENTRATE FOR ARMOR

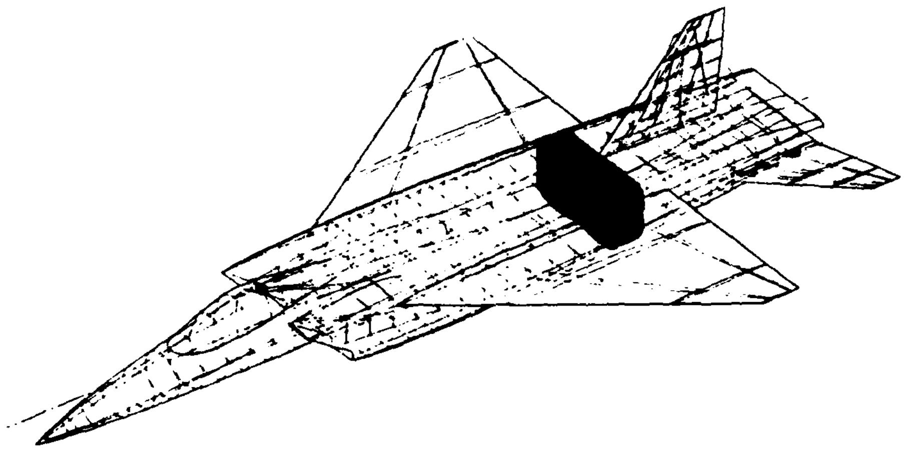
D - DISPERSE REDUNDANT SYSTEMS

E - END FUEL FIRES

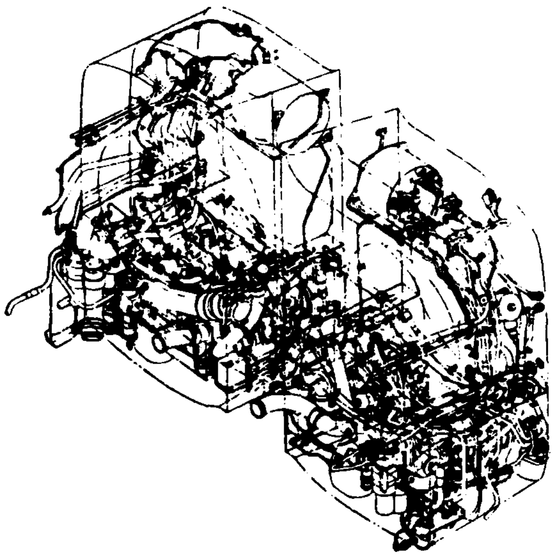
Everything must be kept simple in conceptual design, even vulnerability guidelines. The A B C's of vulnerability, created in the 60's, have served as design guides to the airplane configurator.

- Armor, while listed first, is usually the last resort. Except for pilot protection, armor is usually not included during conceptual design.
- Bury critical elements which would yield a K or A kill. During conceptual design the critical element list includes, ammunition drum, engines, flight control computer, power distribution panel, emergency power generator.
- Concentrate critical elements when armoring is necessary. This is usually done during the second iteration following preliminary analysis for vulnerable areas.
- Disperse redundant elements. A standard approach that produces the maximum separation possible between vulnerable components.
- End fuel fires - a reminder to avoid fires by including inert gas, foam of other explosion protection and fuel tank arrangements that do not leak on the hot sections.

DISPERSE REDUNDANT SYSTEMS



Dispersal of redundant components has to be achieved through configuration arrangement. Dispersal of redundant subsystems may require entire sections of internal bays. Major equipment, structural arrangement and accessibility will produce constraints on dispersal. Such limitations result in the "dispersed" zone shown here and discussed on the following page.

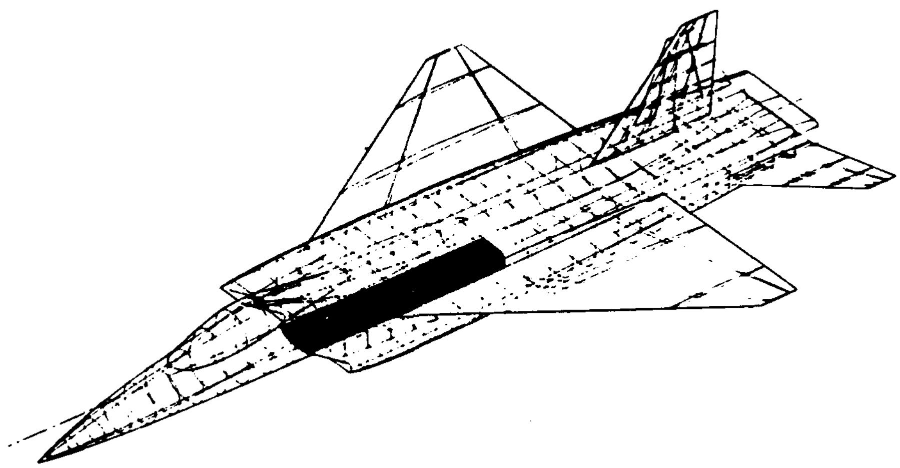


DISPERSE REDUNDANT SYSTEMS

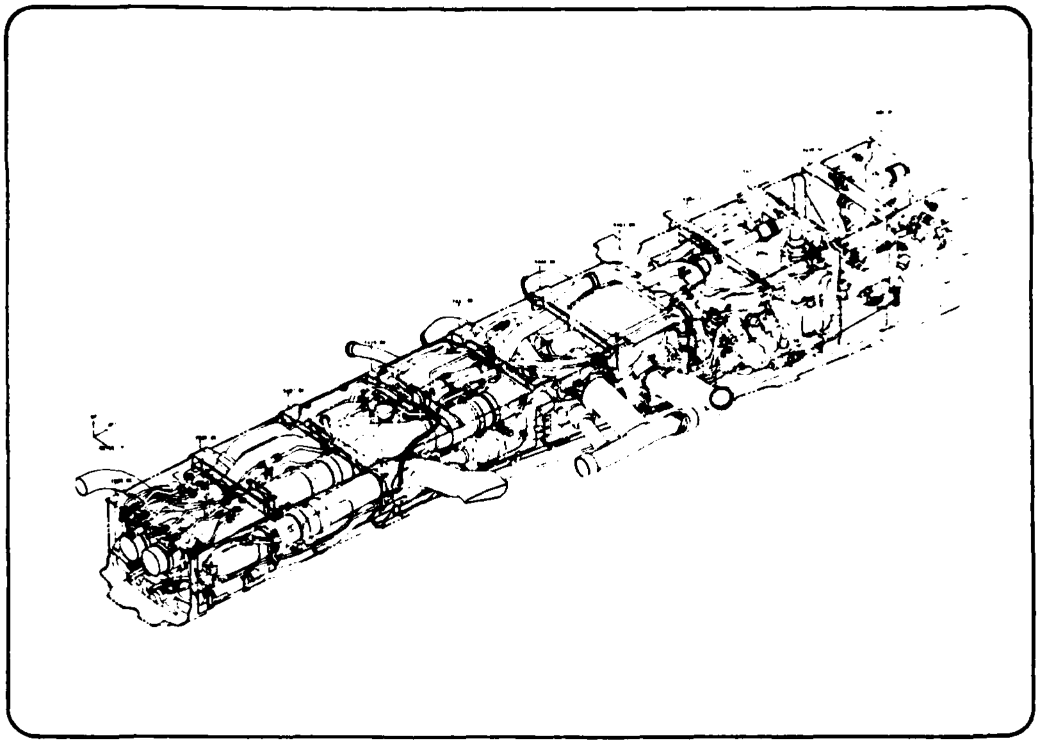
When design development progresses, the detail of subsystem vulnerability gets compromised by maintainability and accessibility considerations. The conceptual designer carries his integration skills forward in development to maintain the discipline in subsystem installations. Detail vulnerability studies are aided by evolving computer generated layouts where the initial stored data is continually updated and expanded to produce, in the end, total detail of all subsystem installations.

This installation of a dual hydraulic system illustrates one end product of dispersed redundant systems.

BURY VULNERABLE COMPONENTS



A typical location for buried subsystems is shown. Protection of this zone is provided by engine inlet structure, forebody structure and components and external stores hardpoints. The following page discusses this in more detail.



ECS SYSTEM

The vulnerable components of concern here are actually above the Environmental Control System shown. Critical avionics and ammo drum are buried above the ECS, behind the pilot and ahead of integral body fuel tanks, thus minimizing armor requirements in the forebody.

Producing total subsystem details, such as shown, produce early results for vulnerable area studies. Computer generated drawings in three dimensions are the key to rapid analysis.

SUMMARY

INTERACTIVE COMPUTER GRAPHICS

WILL :

- INCREASE ACCURACY AND DEPTH OF CONCEPTUAL DESIGN,
- PROVIDE A COMMON DATA BASE FOR DESIGN AND ANALYSIS,
- REDUCE THE TEDIUM OF MANUAL CONSTRUCTIONS, DIGITIZING AND MEASURING.

WILL NOT :

- REDUCE THE TIME FOR CONCEPTUAL DESIGN,
- COME ABOUT WITHOUT A DEDICATED EFFORT,
- BE UNIVERSALLY ACCEPTED BY ALL DESIGNERS,
- REPLACE THINKING.

The impact that interactive computer graphics has had on the design process can be summarized as having increased accuracy and depth of aircraft designs in both the conceptual and preliminary design phases. While the initial time to design an aircraft concept has not shown any significant benefit, the quality of the product has. The reason for this phenomenon has been given as: if a designer is given a specific period to design something, he will take exactly that amount of time. The computer graphics tool speeds up the drawing process, freeing the designer to think of improvements and refinements.

A secondary benefit of aircraft designed using computer graphics is that it provides a common data base for the analyst as well as the designer. This data base reduces the time and tedium of manual digitizing and measuring, thus, providing more time to analyze data and iterate the design.

Above all, we must remember that the computer does not replace thinking.

COMPUTER-AIDED ENGINEERING
APPLICATIONS AND INTEGRATION WITH S/V

R.J. Ridgeway and J.G. Avery
Boeing Military Airplane Co.
Advanced Airplane Branch
Seattle, Washington

R.J. RIDGEWAY
BOEING MILITARY AIRPLANE CO.

J.G. AVERY
BOEING MILITARY AIRPLANE CO.

COMPUTER-AIDED ENGINEERING APPLICATIONS AND INTEGRATION WITH S/V

R.J. Ridgeway and J.G. Avery
Boeing Military Airplane Co.
Advanced Airplane Branch
Seattle, Washington

Survivability analysts have always made good use of digital computers. Additionally, one of our primary goals has been to integrate survivability design technology into the design process at the very earliest opportunity. Computer-aided design (CAD) is well-suited to the skills and goals of the survivability community.

Largely as a result of the ATS Study, there has been an increasing interaction between design and effectiveness analysis. Design decisions and technology development are influenced to a major degree by the results of system analyses, which express merit in terms of targets killed per dollar, as an example. As these decisions are made during conceptual design, it is essential that survivability parameters are computed with the same level of accuracy as other design parameters. Full implementation of survivability analysis into CAD will assure that this capability is achieved.

The remaining viewgraphs summarize the CAD implementation approach being implemented by the Advanced Airplane Branch of BMAC and indicate certain capabilities that we feel are desirable for the survivability integration.

-COMPUTER AIDED ENGINEERING-

APPLICATIONS & INTEGRATION WITH S/V

PART 1 -R.J.RIDGEWAY
PART 2 -J.G.AVERY

BOEING MILITARY AIRPLANE CO.
ADVANCED AIRPLANE BRANCH
SEATTLE WASH.

JTCG/AS MEETING

" A WORKSHOP IN SURVIVABILITY & COMPUTER AIDED DESIGN "

FT.WORTH,TEXAS

6-9 APRIL 1981

JTCG.CHT
2 APRIL 81

WHERE DOES COMPUTER-AIDED DESIGN APPLY?

	DESIGN	ANALYSIS	MANUFACTURING	ACCURACY
CONCEPTUAL DESIGN (20+ CONFIGURATIONS)	CONFIGURATION LAY-OUT	FUNDAMENTALS		LOW
PRELIMINARY DESIGN I (2-3 CONCEPTS)	PRELIM. INBOARD PROFILES	HIGHER LEVEL PROGRAM ANALYSIS	MODELS & MANUFACTURING CONCEPTS	HIGHER
PRELIMINARY DESIGN II (1 CONFIGURATION)	DETAIL LAY-OUT	HIGHEST LEVEL ANALYSIS	MOCK-UP TOOLING	HIGHEST
DETAIL DESIGN	✓	✓		AS REQUIRED
MANUFACTURING	TOOL DESIGN	OPERATIONS & MATERIAL FLOW	MASTER DIMENSION DATA AND N/C TAPE CAPABILITY	AS REQUIRED

?

CAD

CAM

BOEING

DATA GRAPHICS APPLICATIONS

COMPUTER-AIDED CONCEPTUAL/PRELIM. DESIGN

WHAT CAPABILITIES ARE NEEDED ?

GEOMETRY

CREATION
DISPLAY
ANALYSIS
REPRODUCTION
MANIPULATION & MODIFICATION

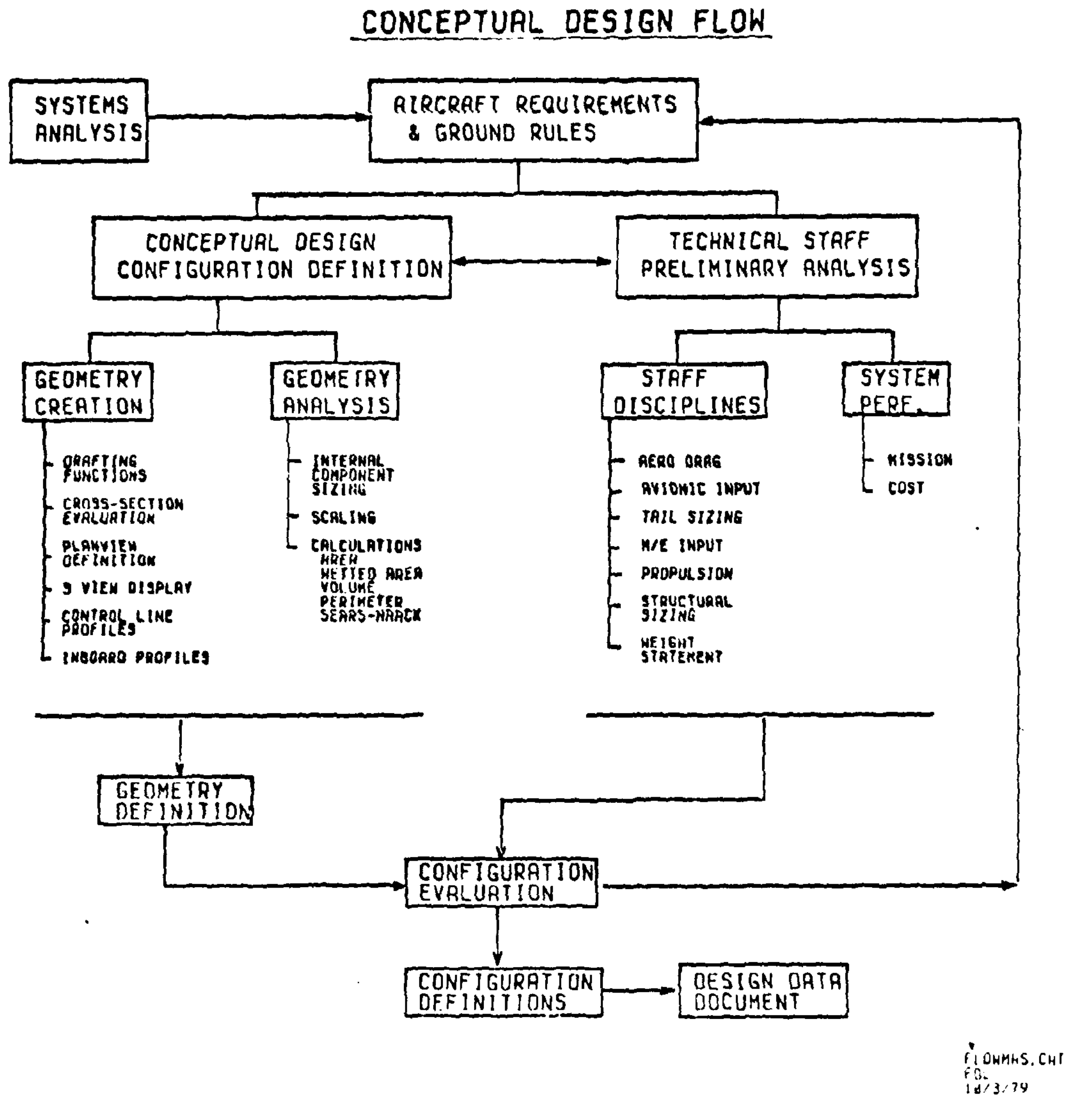
ANALYSIS

TECHNOLOGY DISCIPLINES
COSTS

FDL14.CHT
10/3/79

BOEING

DATA GRAPHICS APPLICATIONS



BOEING
DATA GRAPHICS APPLICATIONS

WHAT COMPUTERS & PERIPHERALS SATISFY CONCEPTUAL CAD NEED ?

O MAINFRAME OR MINI ?

O SELECTION CRITERIA

COST
CAPABILITY
GROWTH
VENDOR SUPPORT

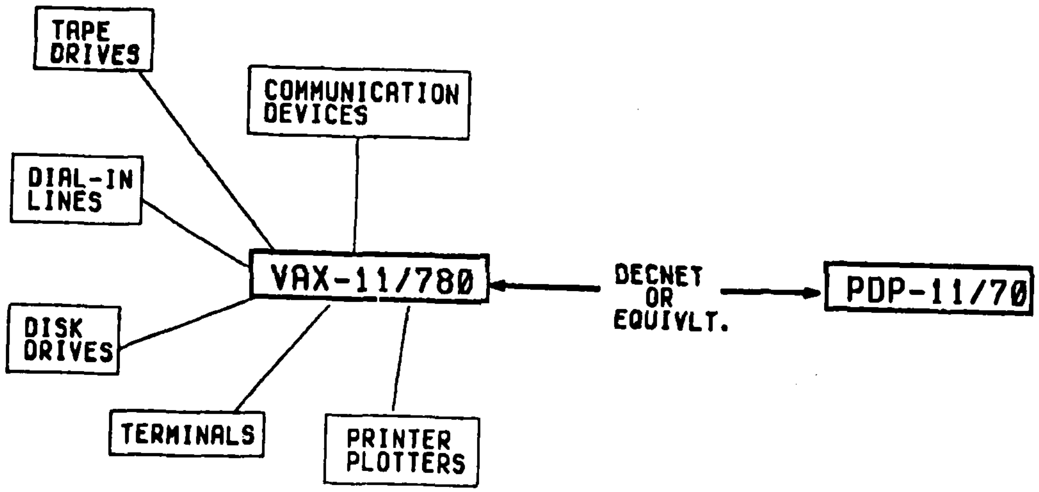
O SELECT MINI

VARIAN
SEL
HARRIS
DIGITAL EQUIPMENT
PRIME
UNIVAC
IBM
OTHERS

FDL15.CHT
10/3/79

BOEING DATA GRAPHICS APPLICATIONS

HOW SHOULD MINI.S BE STRUCTURED ?



CONCEPTUAL CAD PROCESSING

CAD GRAPHICS

FDL17.CHT
10/3/79

BOEING
DATA GRAPHICS APPLICATIONS

PERIPHERAL EQUIPMENT

GEOMETRY CREATION & DISPLAY -- GRAPHICS TERMINALS

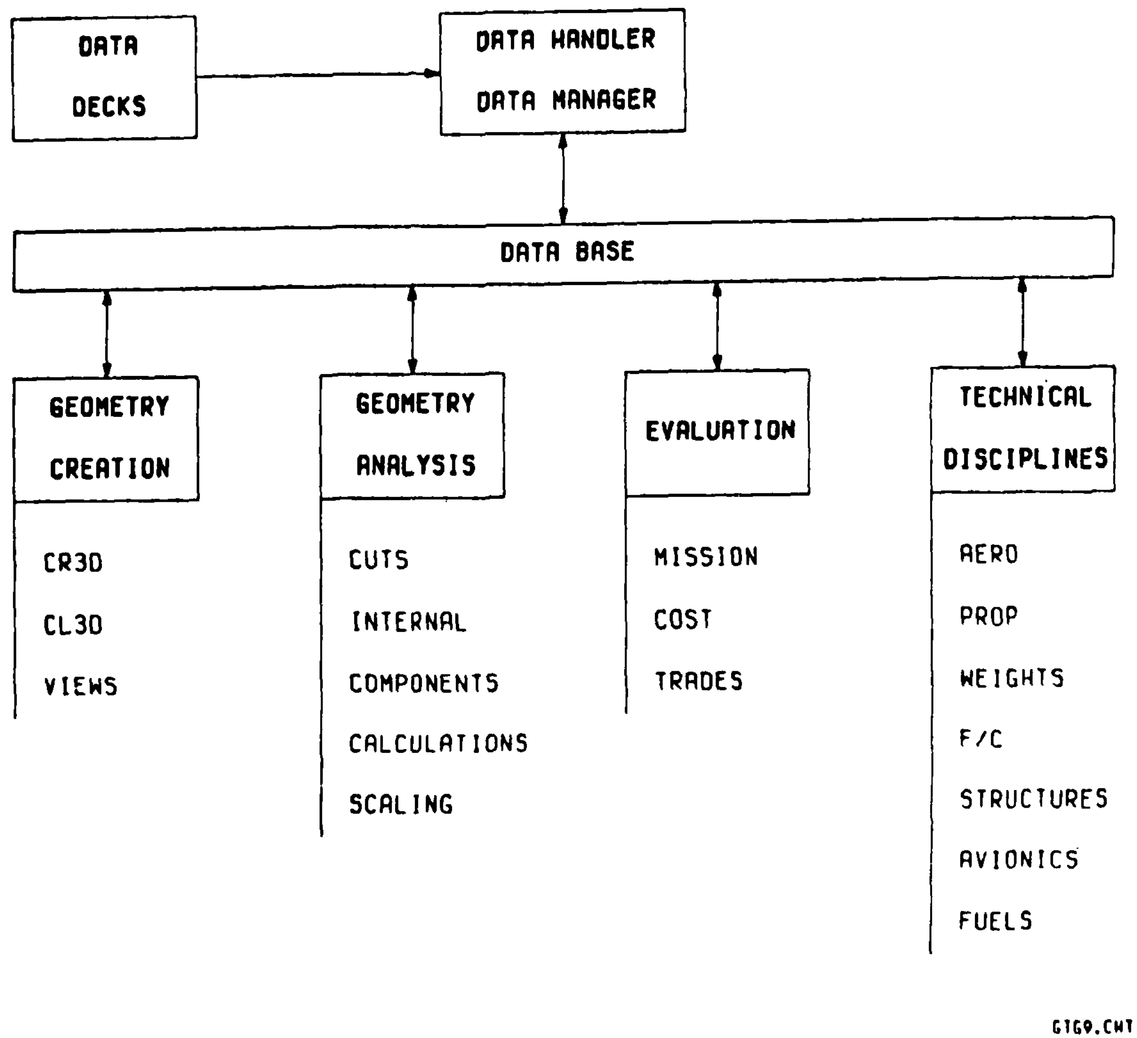
- O ADAGE
- O VECTOR GENERAL
- O TEKTRONIX
- O E & S

REPRODUCTION

- O GOULD
- O GERBER
- O CALCOMP
- O TEKTRONIX
- O VERSATEC

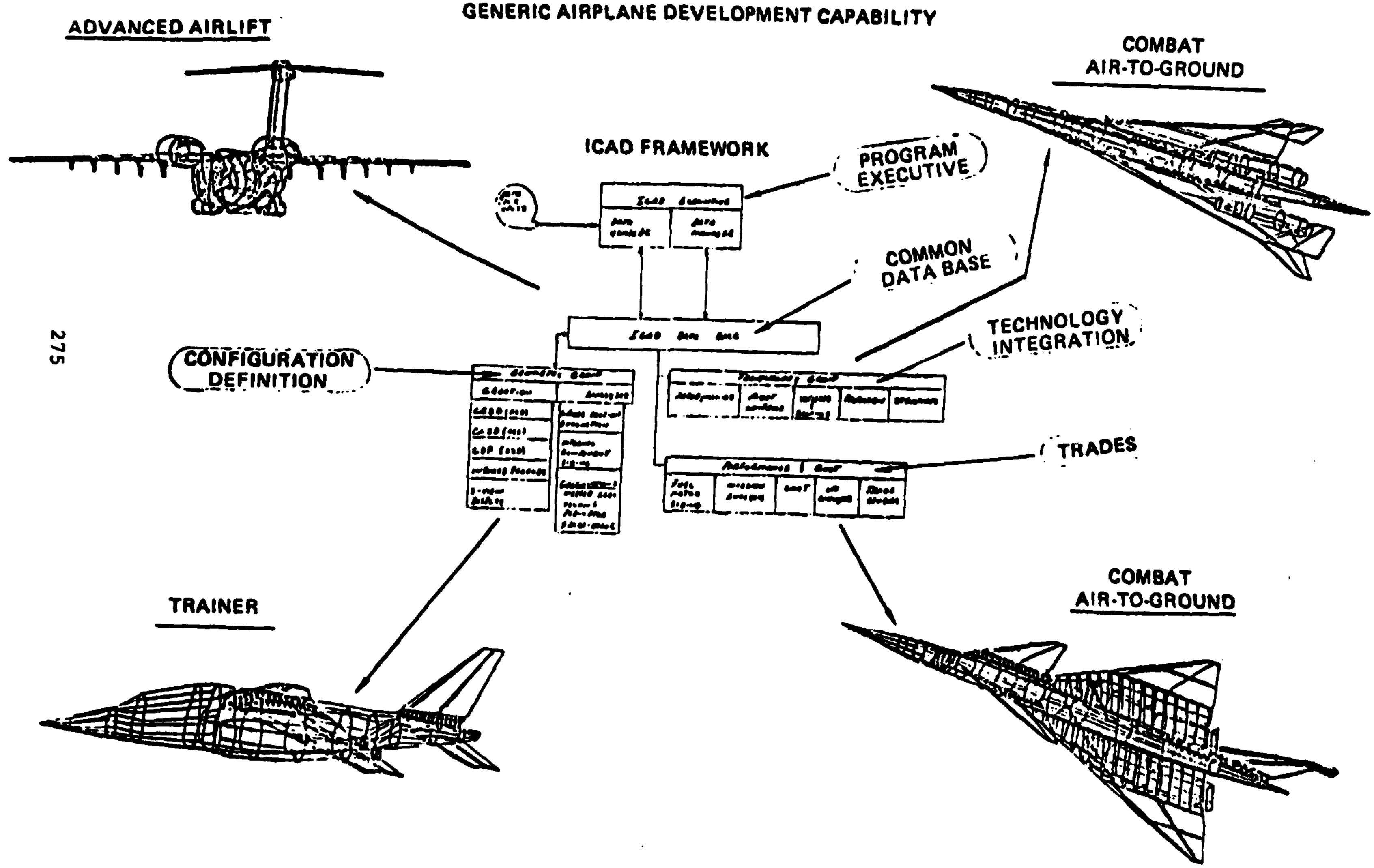
EXPECTED PROGRAM STRUCTURE

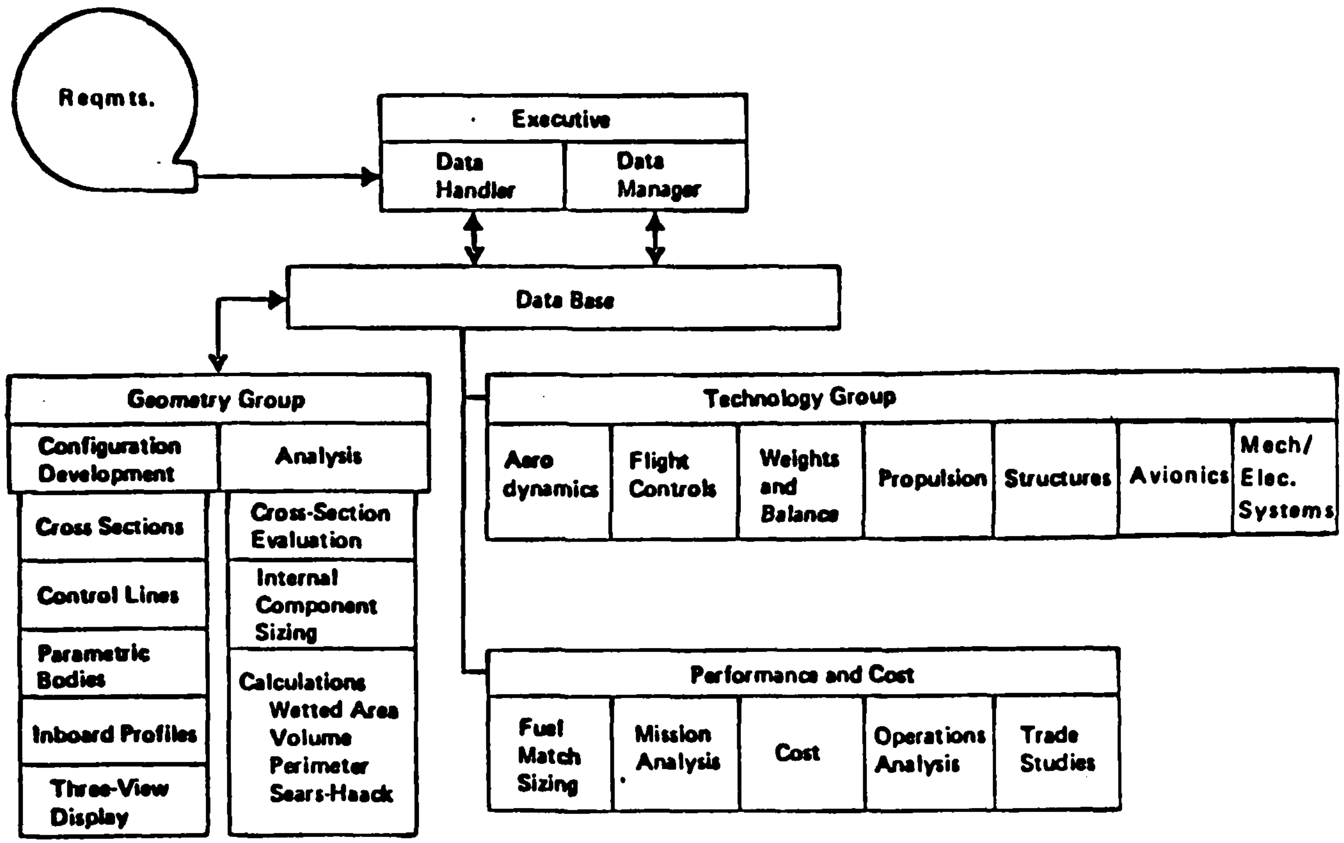
(ONE APPROACH)



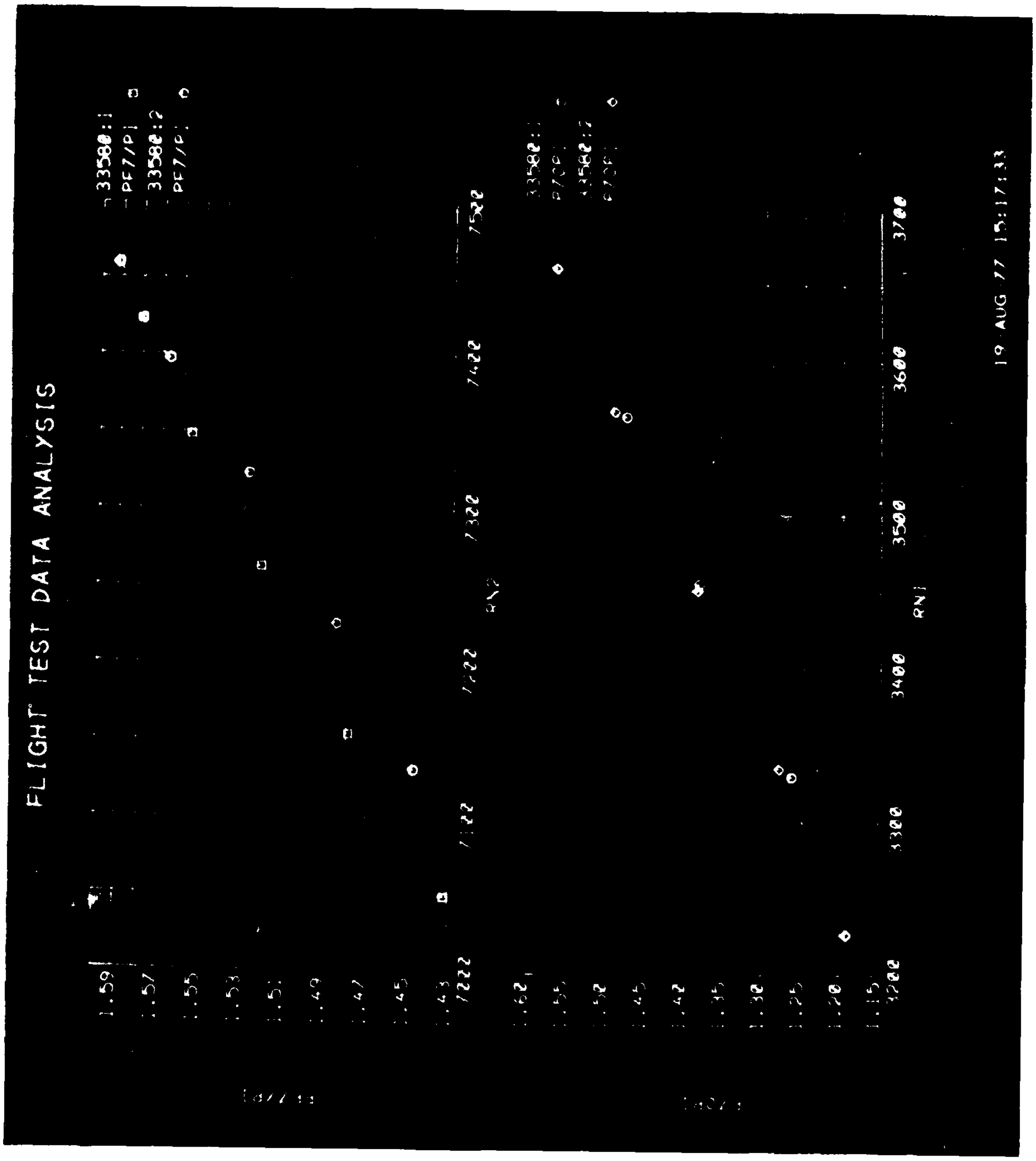
VEHICLE SYNTHESIS SIMULATION & INTEGRATION

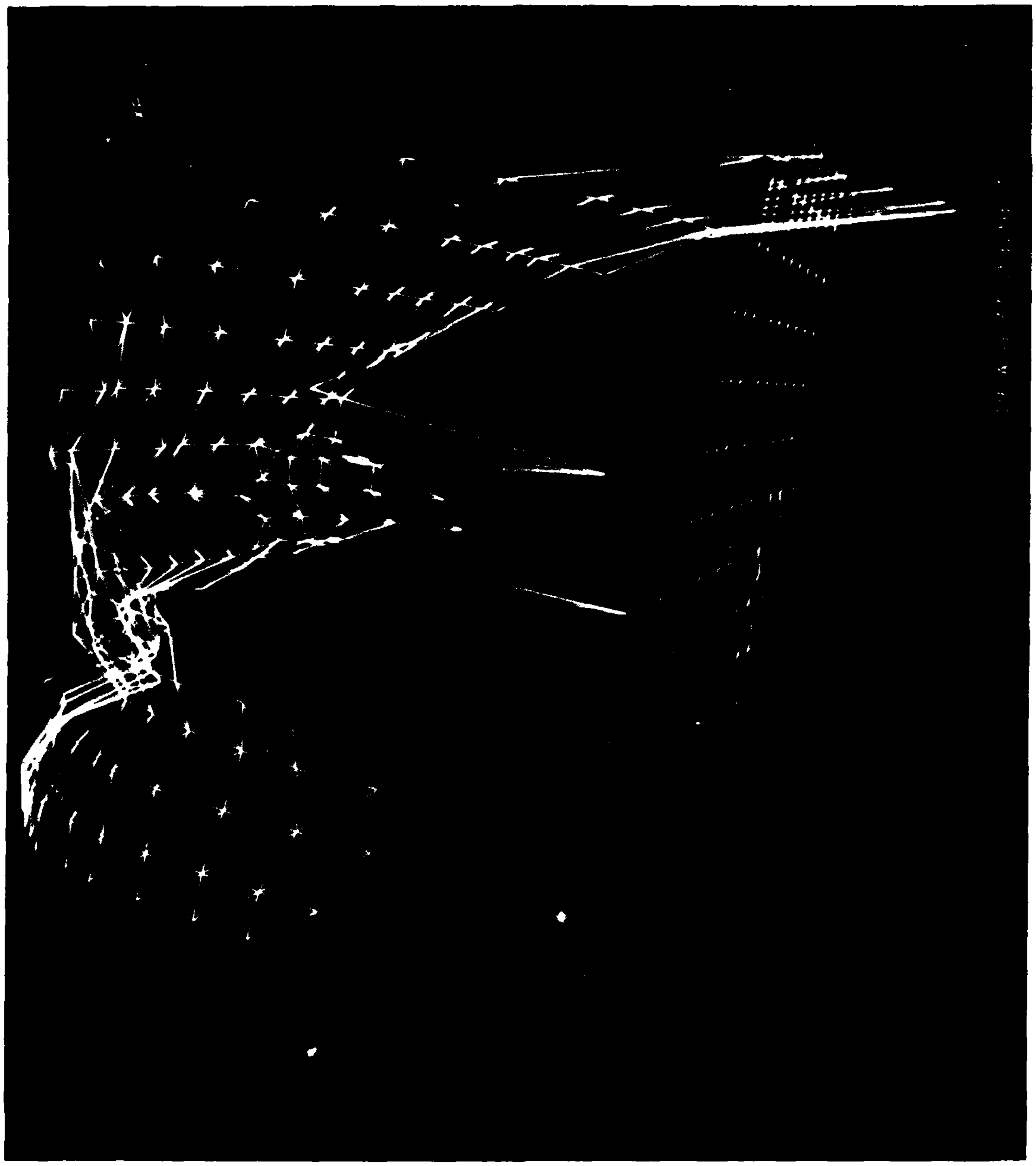
GENERIC AIRPLANE DEVELOPMENT CAPABILITY

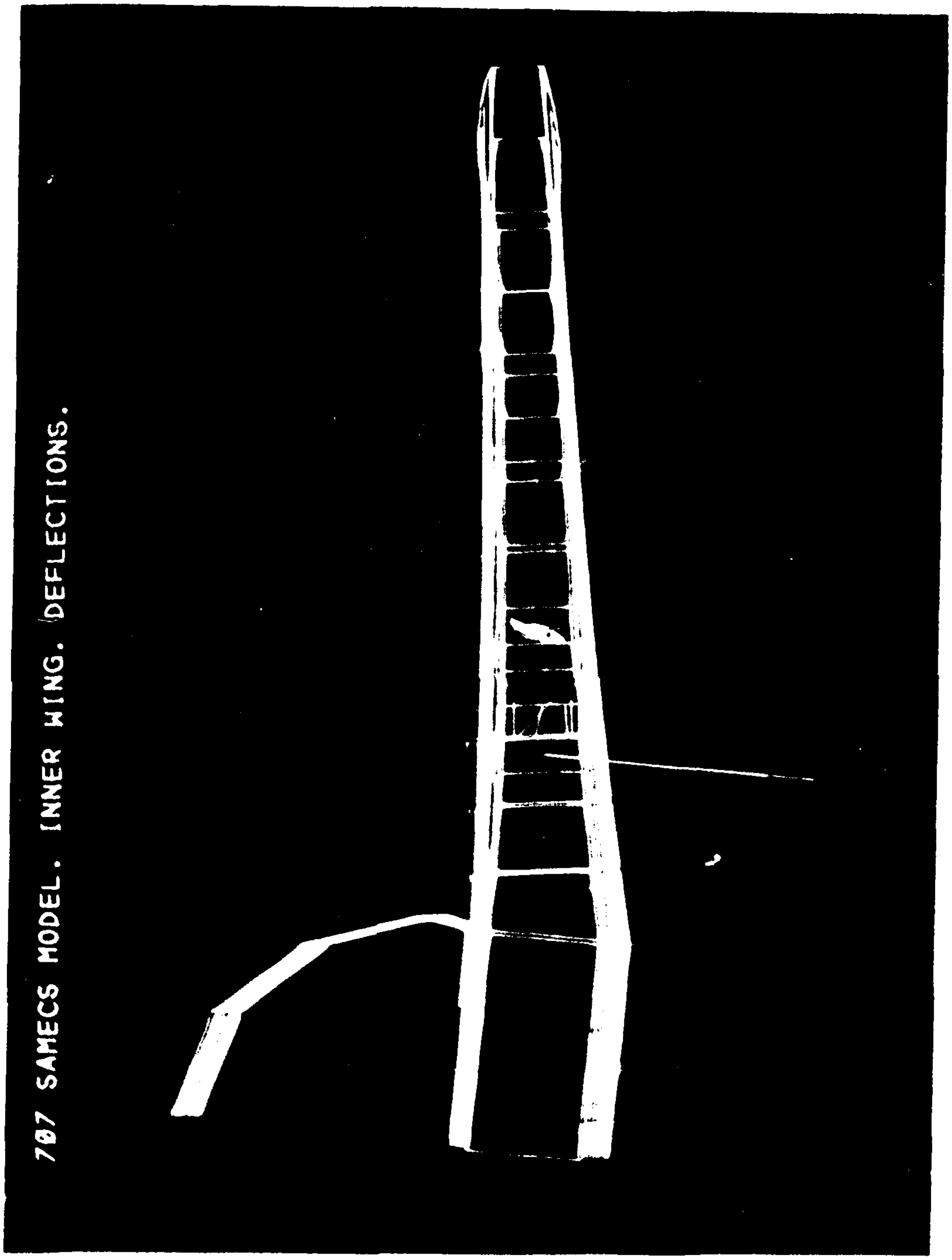


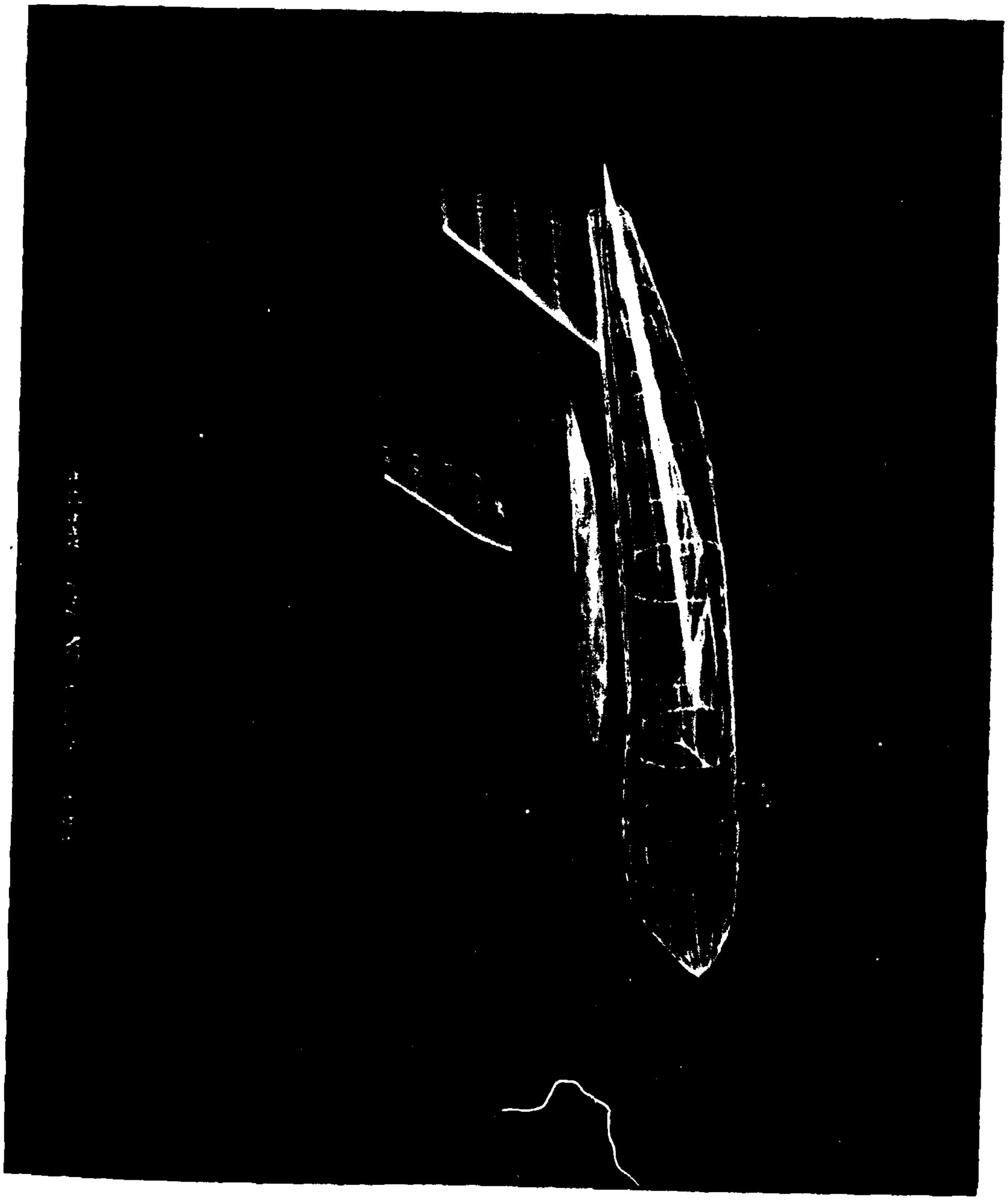


FUNCTIONAL ORGANIZATION


FLIGHT TEST DATA ANALYSIS
19 AUG 77 15:17:33
RN2
RN1
7222
7322
7422
7522
3300
3400
3500
3600
3700
33580:1
PF7/P1
33580:2




707 SAMECS MODEL. INNER WING. DEFLECTIONS.

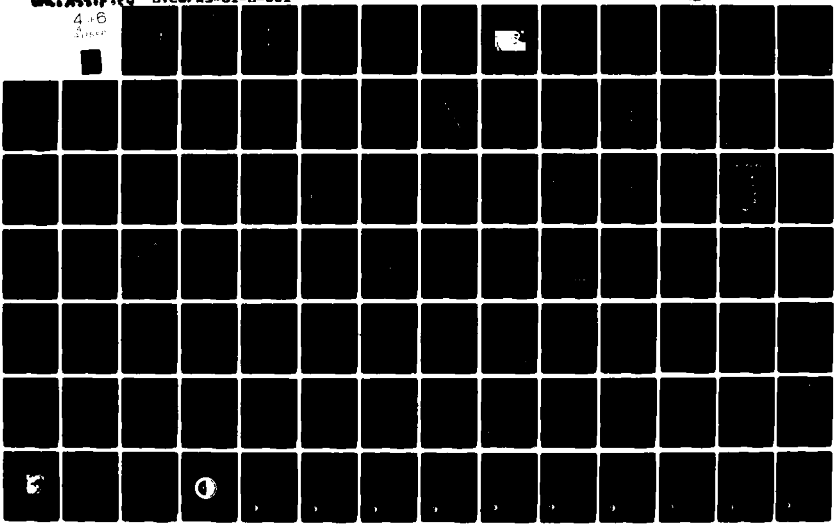


S/V & COMPUTER AIDED DESIGN

- o STATUS,
- o PLANS,
- o THOUGHTS,
- o DESIRES

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-D-001 NL

4 of 6



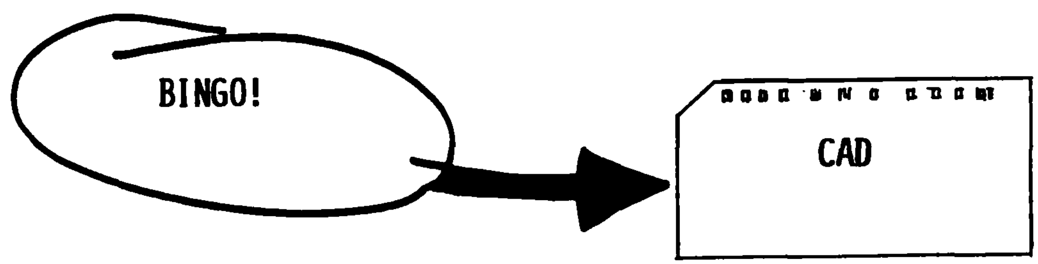
UNC

AD
A113

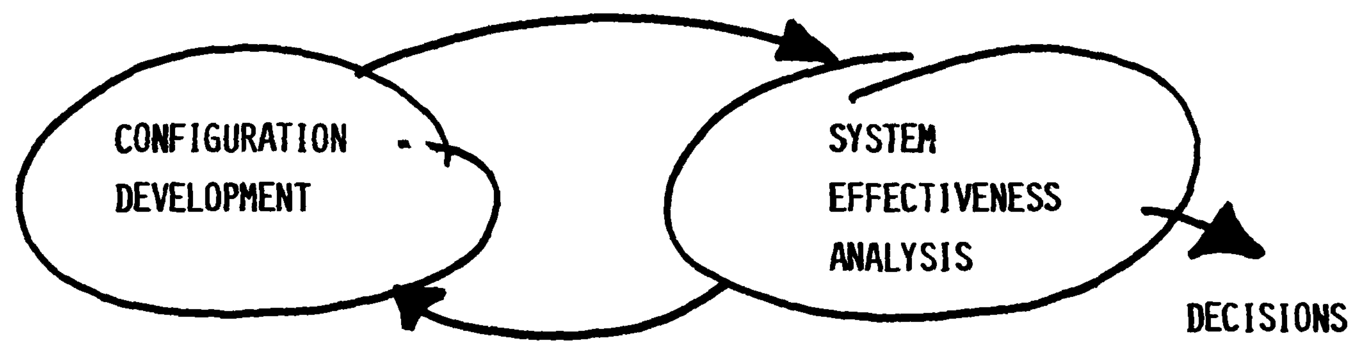
S/V & CAD ARE MADE FOR EACH OTHER

S/V TECHNOLOGISTS...

1) LIKE COMPUTERS
2) WANT TO IMPACT DESIGN



INCREASING INTERACTION BETWEEN
DESIGN & EFFECTIVENESS ANALYSIS



- VULNERABILITY
  - A_V
  - LETHALITY ENVELOPES
- SUSCEPTABILITY

- MISSIONS/THREATS
- ATTRITION
- TARGETS KILLED/$
- COST BENEFIT

PROGRESSIVE VULNERABILITY ANALYSIS LEVELS

STATISTICALLY BASED SCALING MODELS	→	RAPID VULNERABILITY ESTIMATING METHODS	→	DETAILED VULNERABILITY ANALYSIS - FASTGEN - COVART

WHATS GOOD ABOUT CAD?

FROM THE S/V STANDPOINT...

- o THE GEOMETRY
- o THE INTERACTION
- o THE COMMON DATA BASE
- o THE PARTICIPATION

DESIRED S/V-CAD INTEGRATION FEATURES

- o VULNERABILITY/SUSCEPTABILITY MEASURES INCORPORATED AS DESIGN PARAMETERS
- o A COMMON GEOMETRIC MODEL FOR...
  - DESIGN ANALYSIS
  - VULNERABILITY/SUSCEPTABILITY ANALYSIS
- o A VULNERABILITY DATA BANK CONTAINING...
  - COMPONENT LETHALITY
  - COMPONENT SHIELDING
- o INTERACTIVE SHOTLINE ANALYSIS

LET'S NOT FORGET DETAIL DESIGN

COMPLIANCE WITH SUBSYSTEM SPECS REQUIRES...

DETAIL DESIGN ALGORITHMS FOR:

- THREAT DAMAGE
- SUBSYSTEM RESPONSE
- VULNERABILITY LEVELS

THE IMPACT OF COMPUTER GRAPHICS
ON PRODUCT DEVELOPMENT

Richard Ricci
Lockheed-California Company
Burbank, California

THE IMPACT OF COMPUTER GRAPHICS
ON PRODUCT DEVELOPMENT

Richard Ricci
Lockheed-California Company
Burbank, California

Interactive computer graphics development was started at the Lockheed-California Company during the mid-1960s. After several years, this initial development matured into a design drafting package called the CADAM* System. This system has continued to be expanded, and other graphic applications have been integrated with its data base until nearly all aspects of aircraft design have been considered.

CADAM is now used extensively at all major Lockheed companies, including the Lockheed Georgia and Lockheed Missiles and Space Companies as well as the California Company (CALAC). It has also been licensed for use and enjoys wide acceptance as a design/drafting tool throughout the world.

Computer Graphics at CALAC, specifically the CADAM system, is now being used throughout the design Corporation process--from conceptual design through final product support data in the form of maintenance manuals.

In the conceptual, preliminary, and derivative design phase, the graphics system is used to first develop the basic three-view general arrangement drawing. From this information analysis, data models can be generated semi-automatically for input to batch computing mission analysis and aerodynamic programs. These programs perform optimization analysis on the basic aircraft shape and size. This data is fed back to the designer who then modifies the basic configuration as necessary. Also done on the graphics cathode ray tube (CRT) during these early phases of design are interior sizing to satisfy various cargo, passenger and equipment requirements. Once the basic shape has been determined, the designer can generate an air swept (lofted) surface definition of the vehicle and a "structural arrangement" layout. These are used for wind tunnel modeling and structural analysis.

The applications of CADAM in the production design areas of CALAC have been extensive and permeate nearly all areas of engineering. The variety of capability covers such diverse disciplines as airframes, interiors,

* Registered trademark of the Lockheed

instrument layouts, mechanisms layouts and motion studies, hydraulic schematics, electrical design, and paint and markings. Virtually no area remains untouched by graphics. However, much of the current design efforts are still manual. This is mainly because of training requirements of both new and old employees, hardware requirements, and acceptance by middle management.

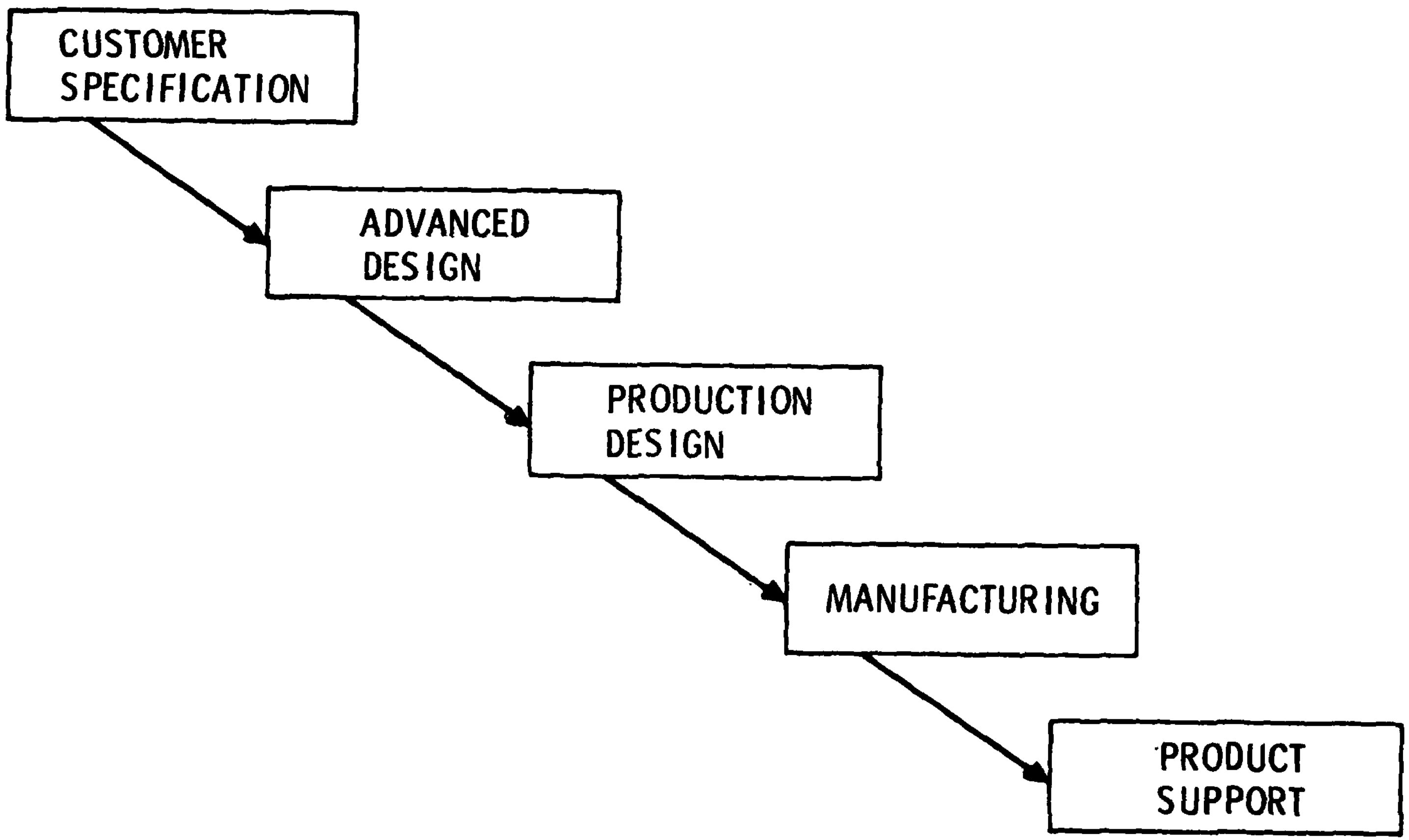
CADAM's use in the manufacturing area of the company ranks among the oldest and most established. Manufacturing began using the system back in 1968 for the programming and generation of numerical control (NC) machine tapes. Today virtually 100 percent of all NC tapes made at Lockheed are done by graphics. In addition to this activity, the tool design and Quality Assurance areas of manufacturing are also now using the system.

Finally, but certainly not least, is the application of graphics in the product support area. These are the people who develop and maintain maintenance manuals. At CALAC this is a 100 percent CADAM endeavor on the L-1011 Trijet project. The size of the task is so large that their current data base is well over 250,000 drawings.

Other major areas of graphics include lofting and analysis modeling. One hundred percent of all CALAC loft data are now generated on graphics. In the analysis modeling area extensive use is being made of the existing and newly created geometry drawings to develop analytical models such as aerodynamic paneling models, finite element models, and survivability assessment models.

THE IMPACT OF COMPUTER GRAPHICS ON PRODUCT DEVELOPMENT AT LOCKHEED CALIFORNIA

THE PROCESS


CUSTOMER SPECIFICATION
ADVANCED DESIGN
PRODUCTION DESIGN
MANUFACTURING
PRODUCT SUPPORT

APPLICATION OF CADAM IN CONCEPTUAL AND PRELIMINARY DESIGN

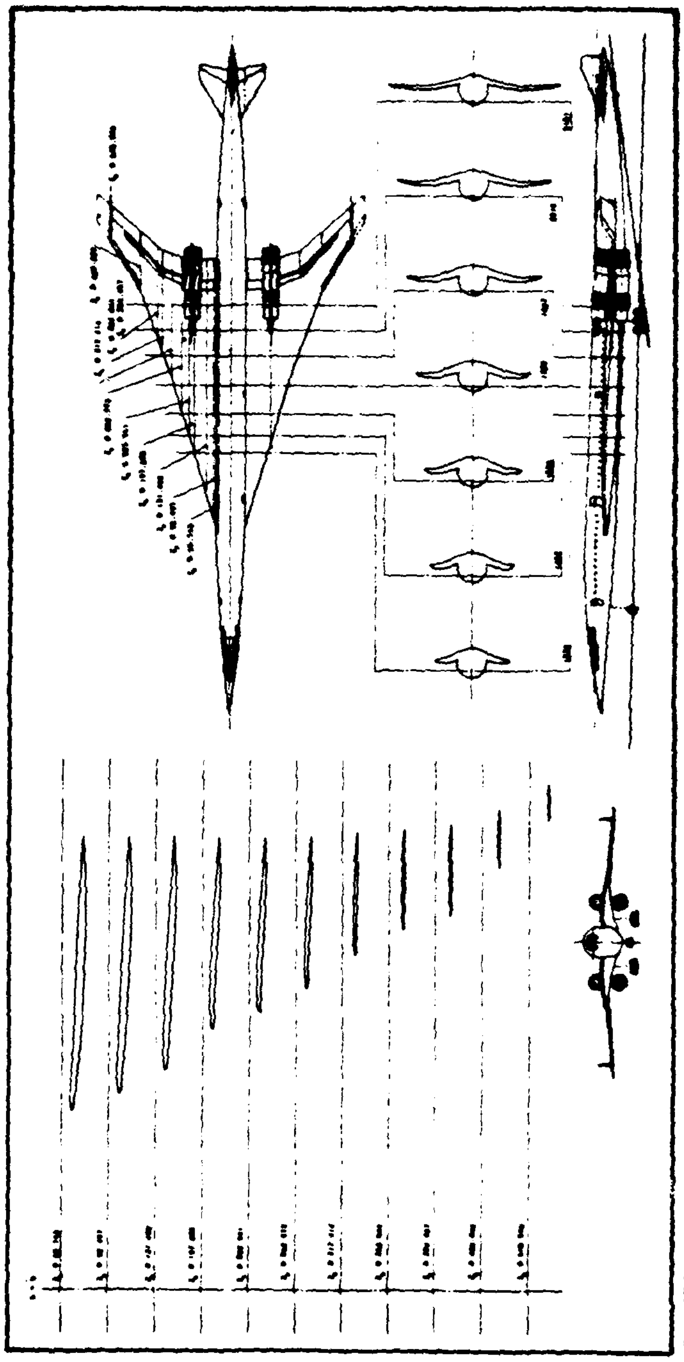
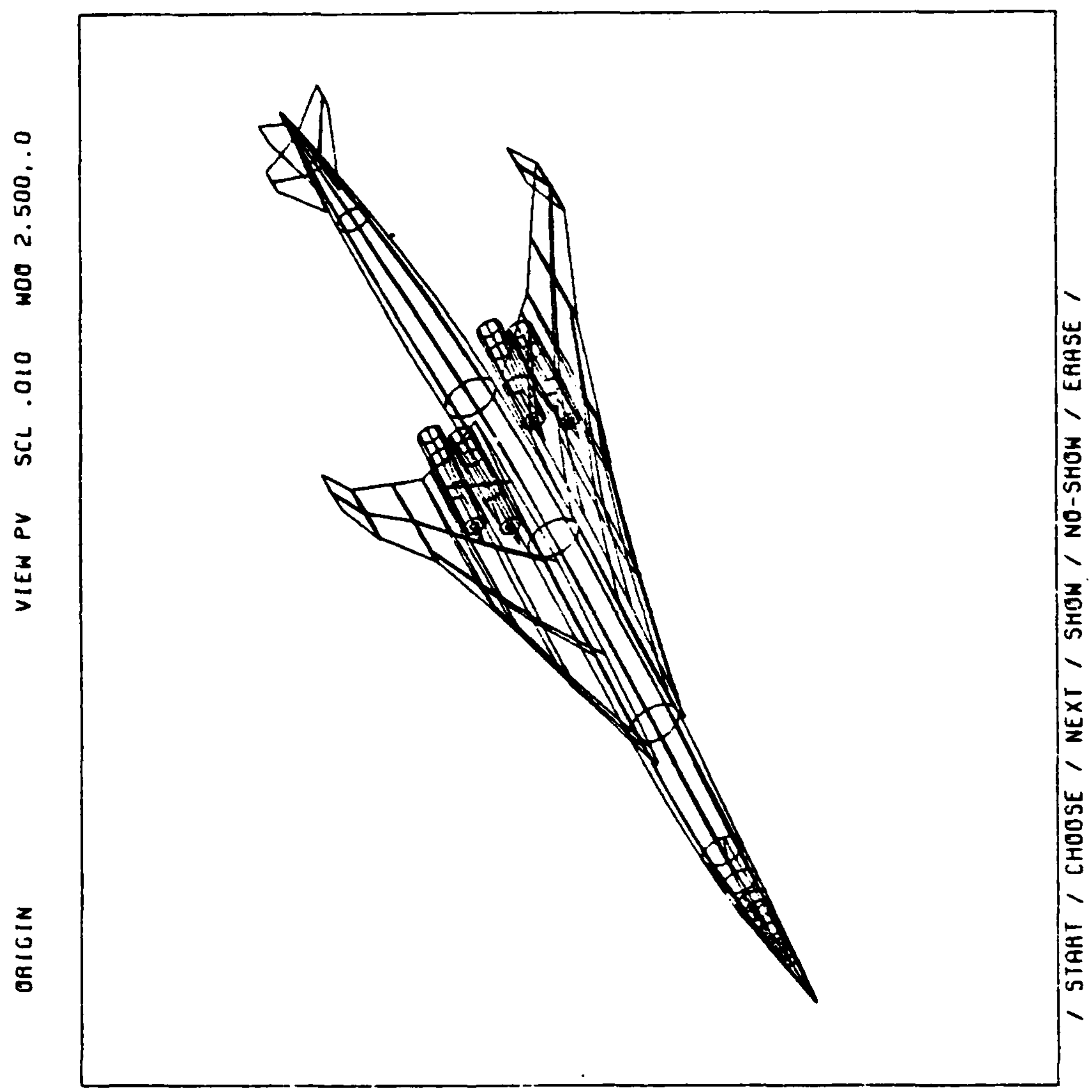
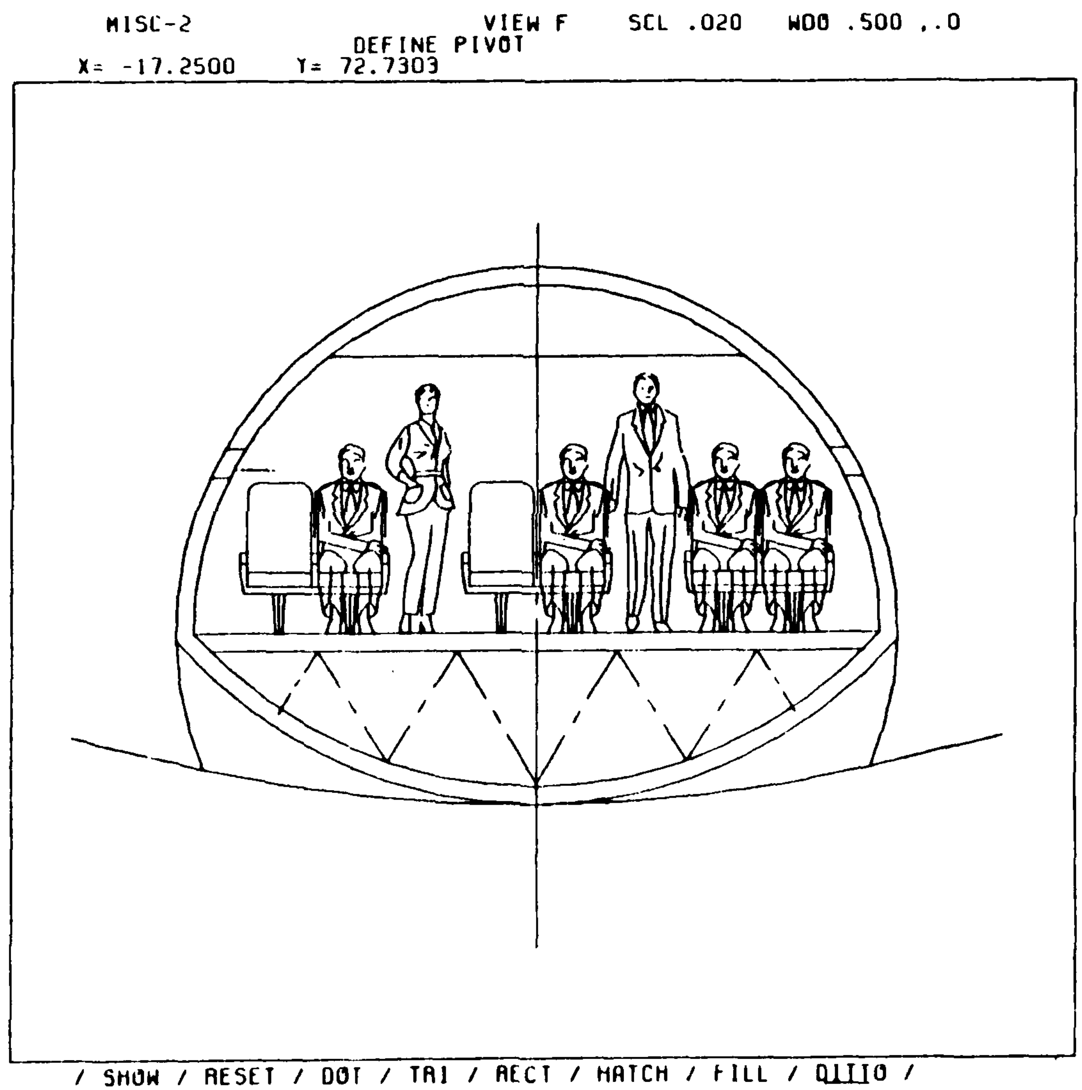
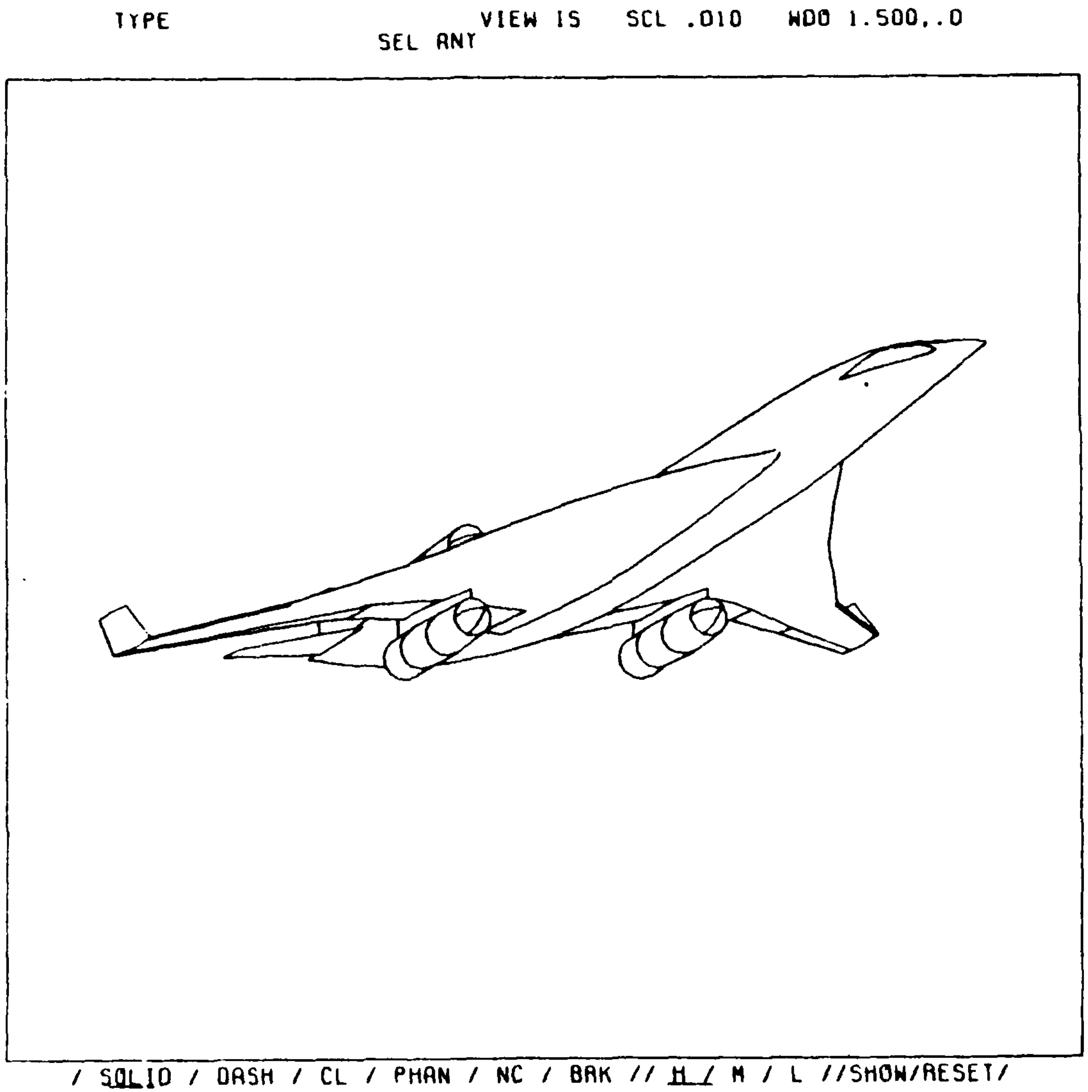


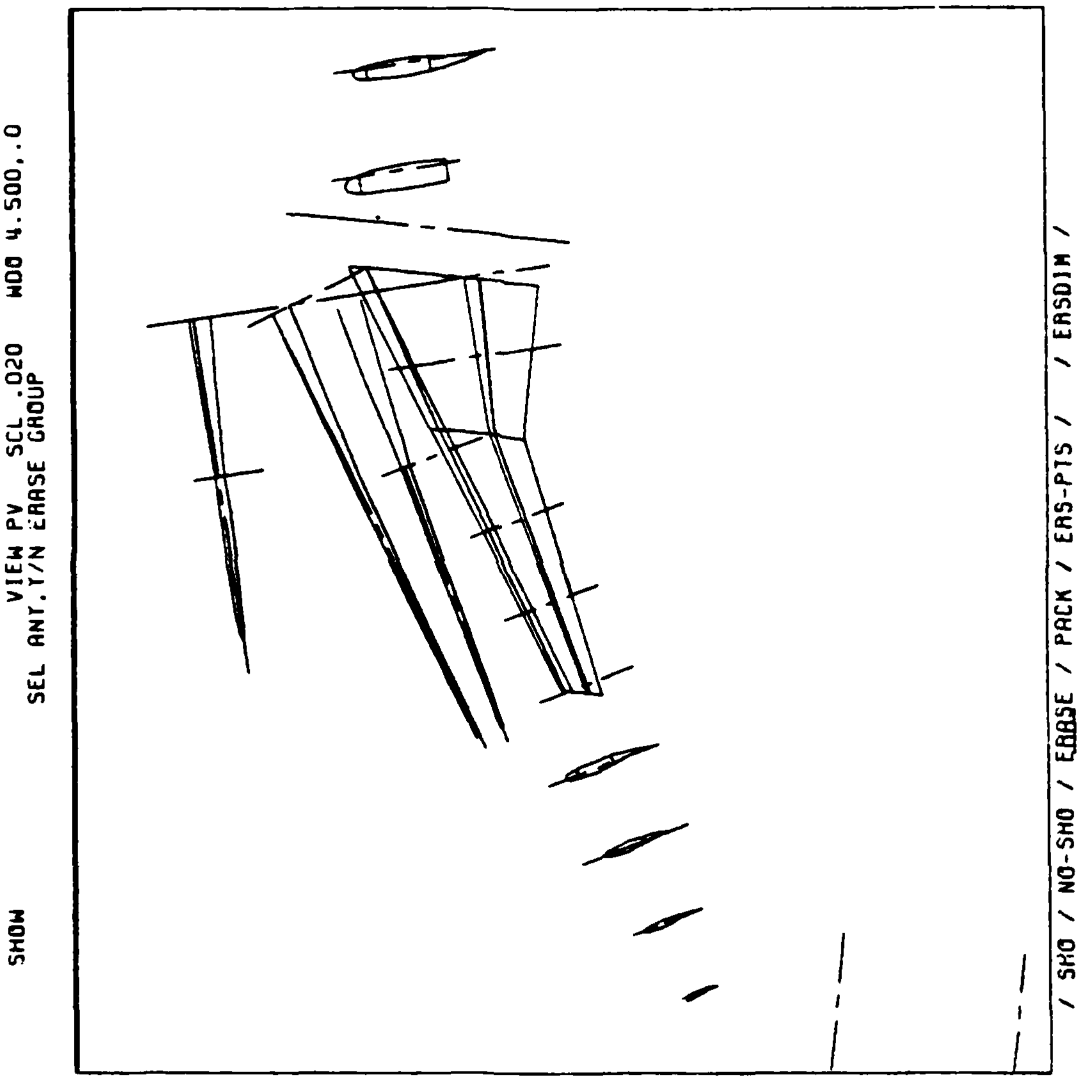
FIGURE 7 NASA Supersonic Cruise Vehicle Configuration Drawing Made With the CADAM System

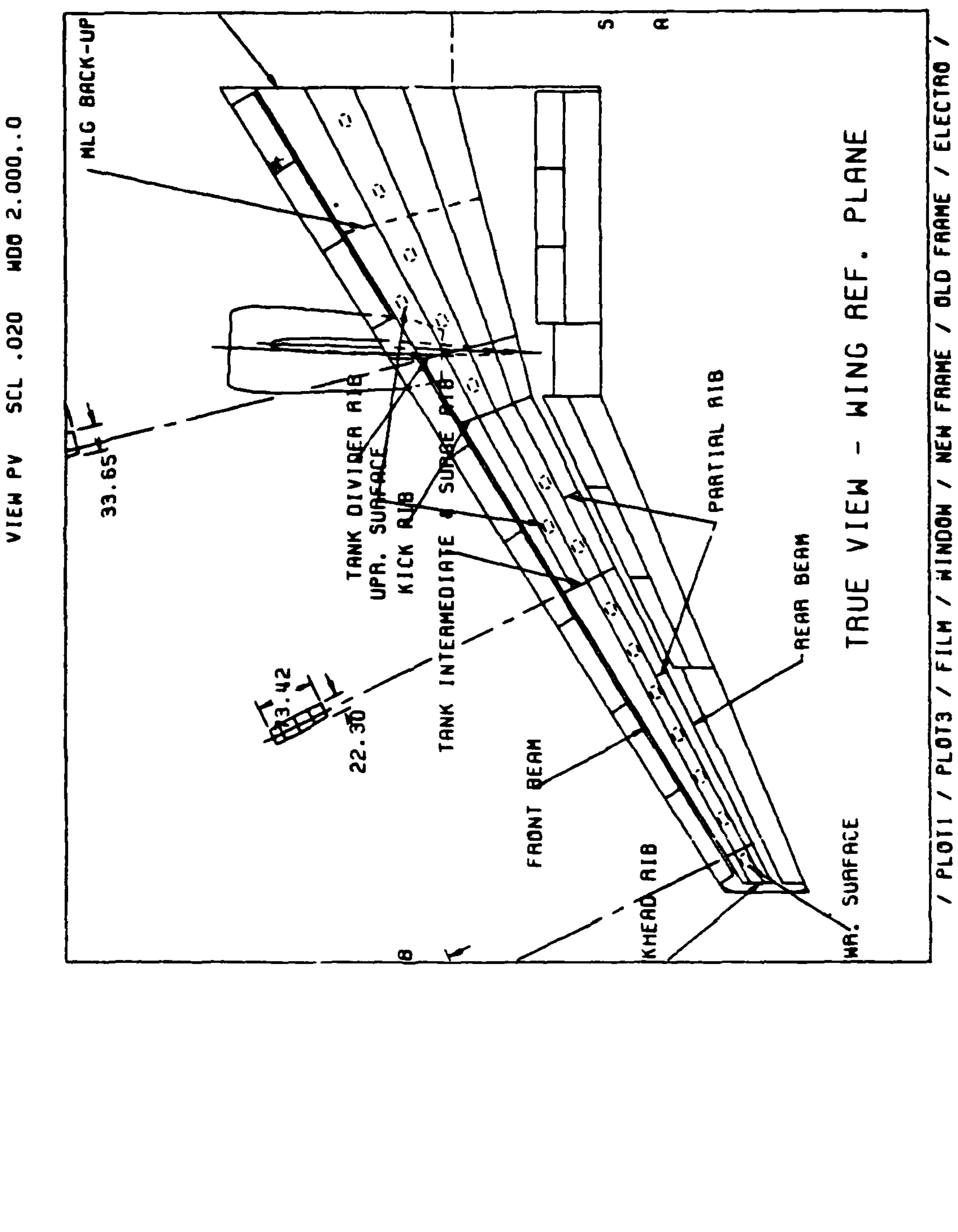
```
                         VIEW PV   SCL .010   WDO 2.000,.0
                      SEL PARAMETER TO MODIFY

 ID=

   GENDATA                  FUEL                        GENERAL
 GROSS WT=496000.000 CFVBOX                         *WING INC=3.000
 THRUST  =50000.000  CSECTB                          THRUST A=.000
 WOS     =140.000    FVOL                            SCRAPE A=12.124
 TOW     =.300       WING REF                        GRDRUN A=12.124
 MACH NO =.830       WTANK1                          GEAR-LEN=140.889
 ALT     =35000.000  WTANK2
 CREW    =11.000     FVFB                                PROPULSN
 PASS    =246.000    VFB                             NENG     =2.000
 PAYLOAD =91300.000                                  REFTHRST=50000.000
 FUEL    =213600.000                                 ENGSCL   =1.000
   HTAIL                                             LENG     =162.815
 S-H     =184844.812      VTAIL                      DENG     =96.001
 AR-H    =3.980      S-V       =78663.062            YINBD    =411.339
 TR-H    =.330       AR-V      =1.610               YOUTBD
 SWPL-H  =39.593     TR-V      =.300
 SWPQ-H  =35.036     SWPL-V    =40.969
 B-H     =857.581    SWPQ-V    =35.000
 CR-H    =322.995    B-V       =356.000              TYPE-I   =3.000
 CT-H    =105.972    CR-V      =340.666              LINLET   =42.146
 MAC-H   =232.164    CT-V      =101.262             *SWET-I   =12746.000
 TOC-H   =.076       MAC-V     =242.581
 X-H     =133.237    TOC-V     =.099
 Y-H     =76.644     X-V       =75.345               N NAC    =2.000
 XCP-H   =120.894    Z-V       =.000                 LNAC     =204.961
*SEXP-H  =139932.000 XCP-V     =153.369              DMAXNAC  =108.261
 SWET-H  =286133.000 SEXP-V    =78663.062            SWETNAC  =43624.000
 VOL-H   =1489372.00 SWET-V    =160850.000           VOLNAC   =1298473.00
                     VOL-V     =1471415.00           TOCNAC   =2.280

                                                     LAVGPYL  =312.000
                                                     HAVGPYL  =33.156
                                                     SPLANPYL=10344.605
                                                     SWETPYL  =21517.000
                                                     VOLPYL   =86538.000
                                                     TOCPYL   =6.600

 / FWD / BACK / WING TABLE / RETURN /
```


ORIGIN
VIEW PV
SCL .010
MOO 2.500,.0
/ START / CHOOSE / NEXT / SHOW / NO-SHOW / ERASE /

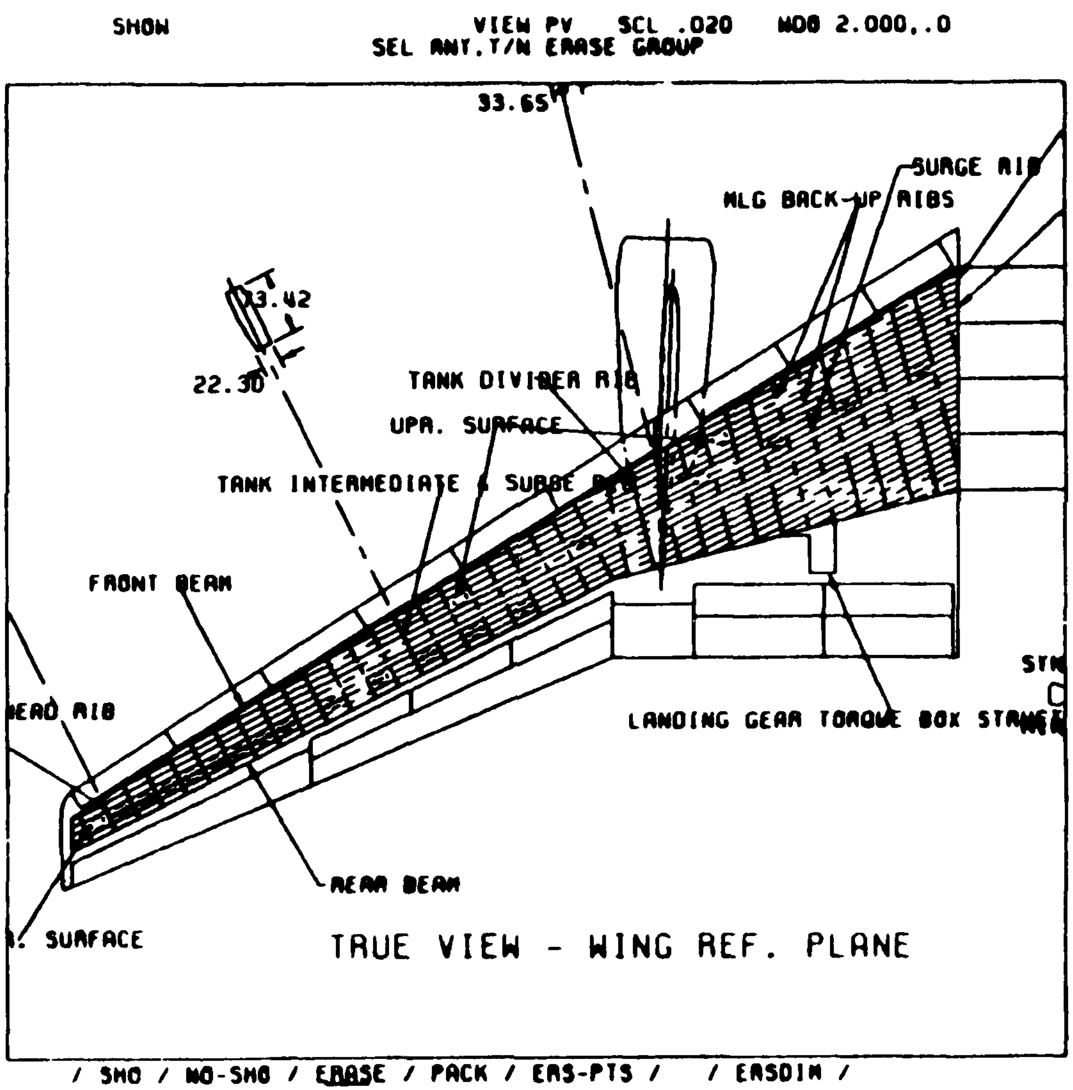

MISC-2
VIEW F
SCL .020
WOO .500 ,.0
DEFINE PIVOT
X= -17.2500
Y= 72.7303
/ SHOW / RESET / DOT / TRI / RECT / HATCH / FILL / QUIT /

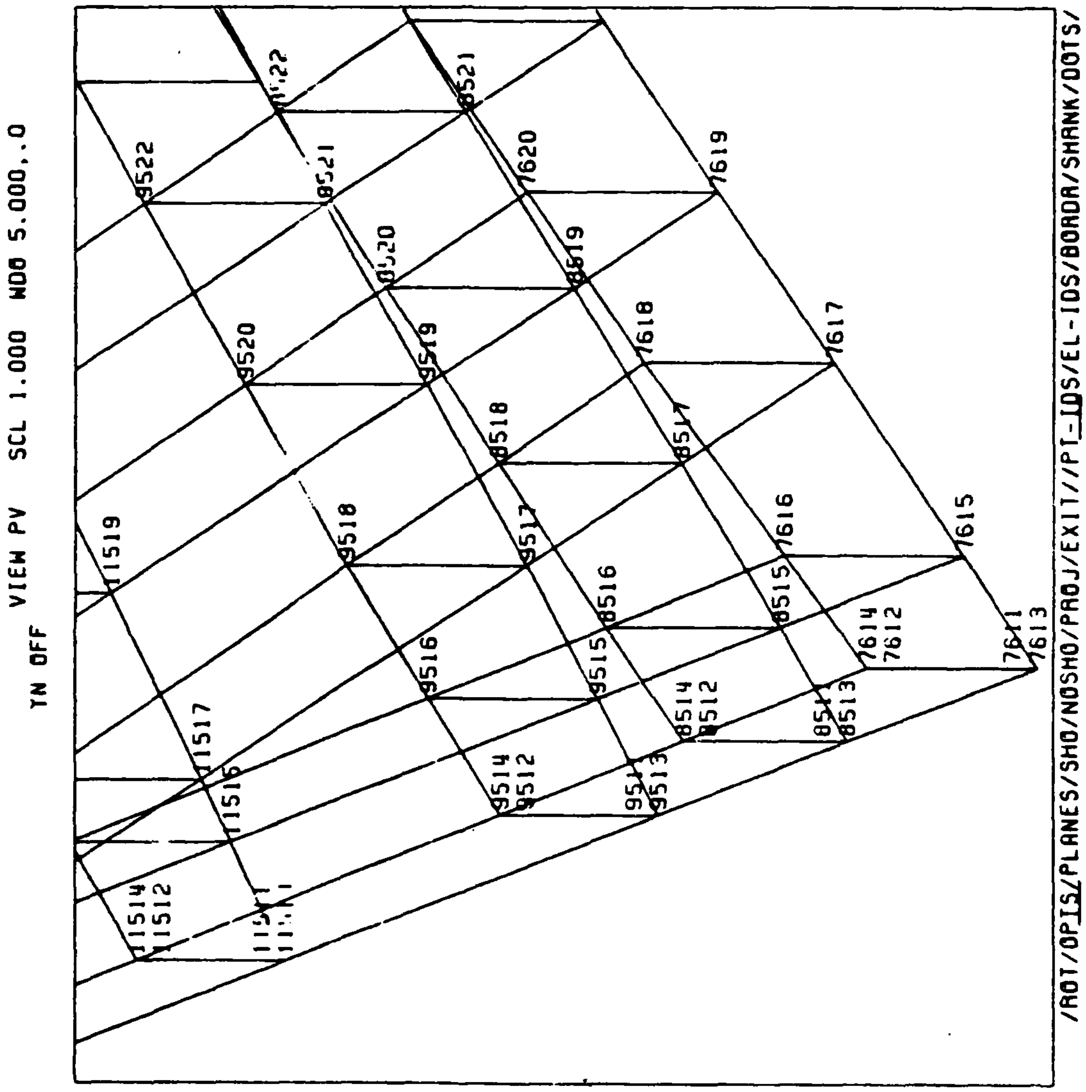

TYPE
VIEW IS SCL .010 WDO 1.500,.0
SEL ANY
/ SOLID / DASH / CL / PHAN / NC / BRK // H / M / L //SHOW/RESET/

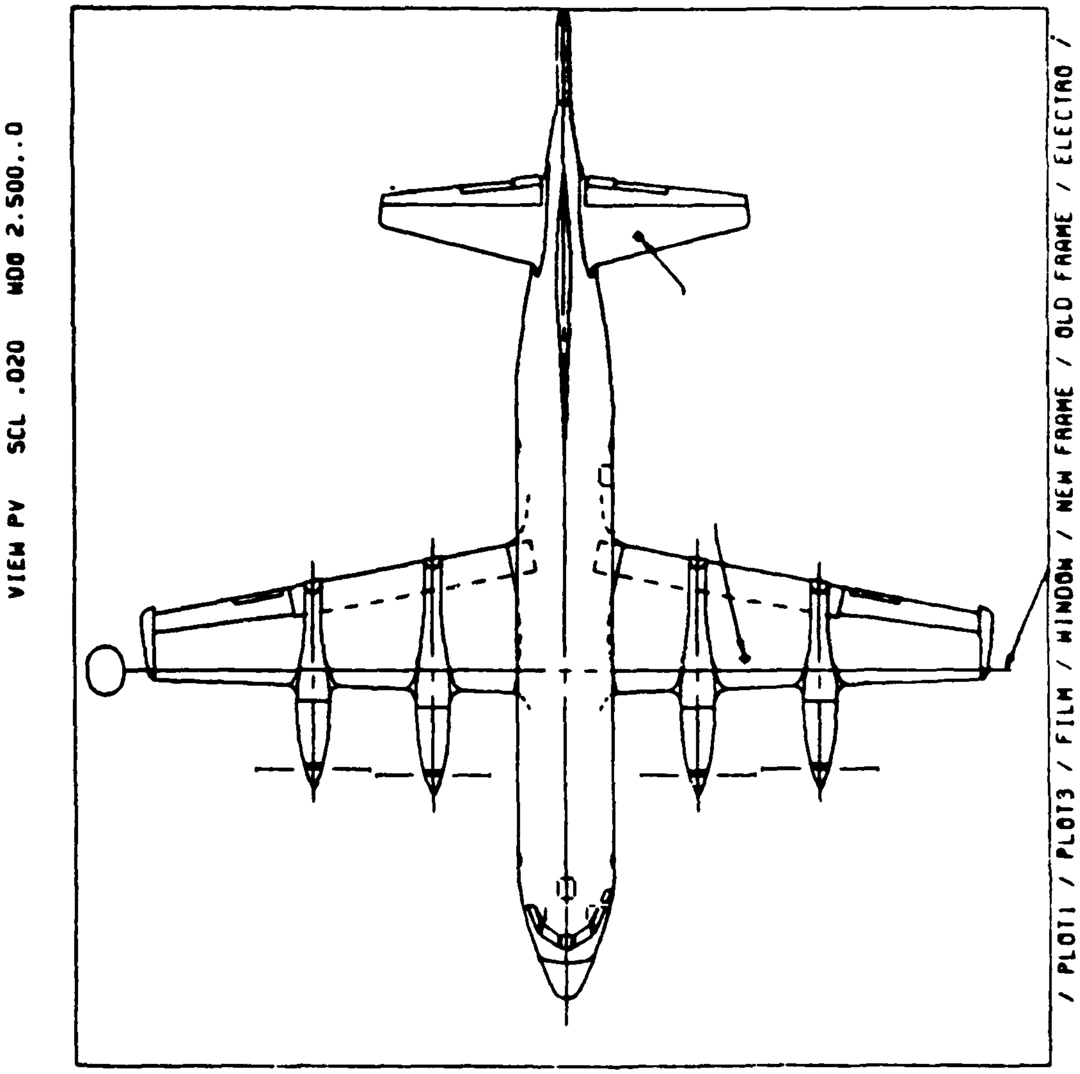

SHOW
VIEW PV SCL .020 WDO 4.500,.0
SEL ANT.Y/N ERASE GROUP
/ SHO / NO-SHO / ERASE / PACK / ERS-PTS / / ERSDIM /

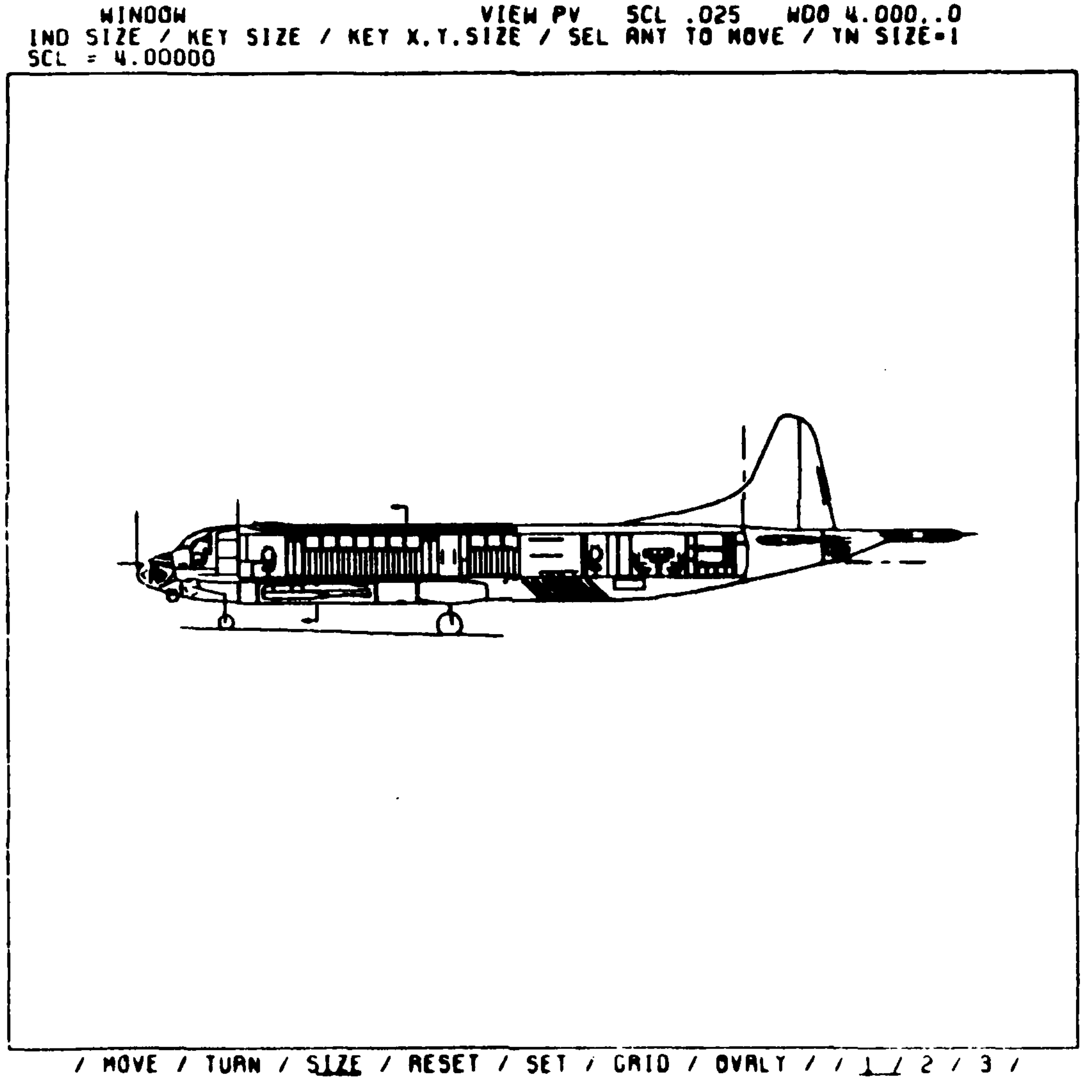


VIEW PV SCL .020 WDO 2.000..0
MLG BACK-UP
33.65
TANK DIVIDER RIB
UPR. SURFACE
KICK RIB
TANK INTERMEDIATE & SURGE RIB
3.42
22.30
PARTIAL RIB
REAR BEAM
FRONT BEAM
KHEAD RIB
WR. SURFACE
S
R
B
TRUE VIEW - WING REF. PLANE
/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

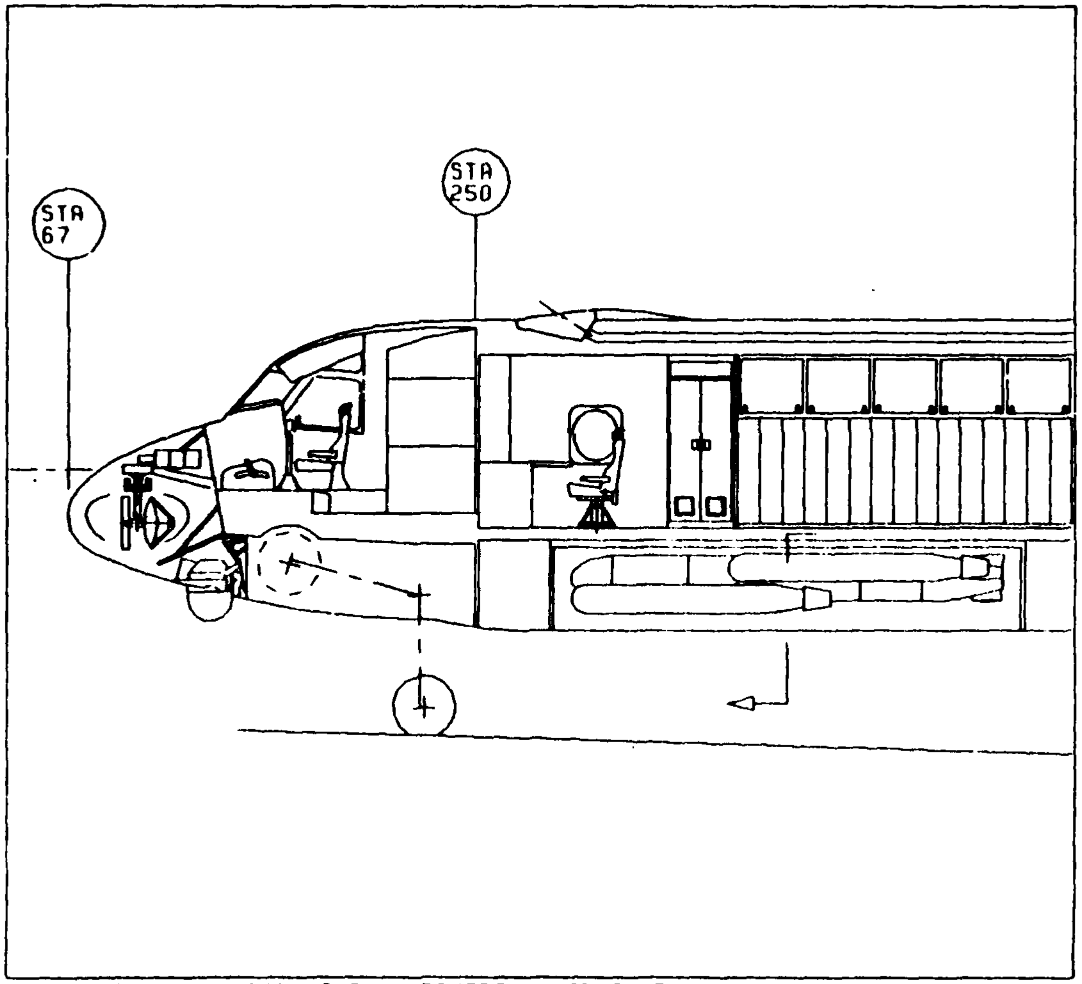

SHOW
VIEW PV SCL .020 WDB 2.000,.0
SEL ANY.T/N ERASE GROUP
33.65
SURGE RIB
MLG BACK-UP RIBS
3.42
22.30
TANK DIVIDER RIB
UPR. SURFACE
TANK INTERMEDIATE & SURGE RIB
FRONT BEAM
EAD RIB
LANDING GEAR TORQUE BOX STR
REAR BEAM
. SURFACE
TRUE VIEW - WING REF. PLANE
/ SHO / NO-SHO / ERASE / PACK / ERS-PTS / / ERSDIM /


YN OFF VIEW PV SCL 1.000 WDØ 5.000,.0
9522
8521
7620
7619
9520
8519
7618
7617
9519
8518
8517
7616
7615
11519
9518
9517
8516
8515
7614
7612
7613
9516
9515
8514
8512
8513
11517
11515
9514
9512
9513
11514
11512
/ROT/OPIS/PLANES/SHO/NOSHO/PROJ/EXIT//PT-IDS/EL-IDS/BORDA/SHANK/DOTS/

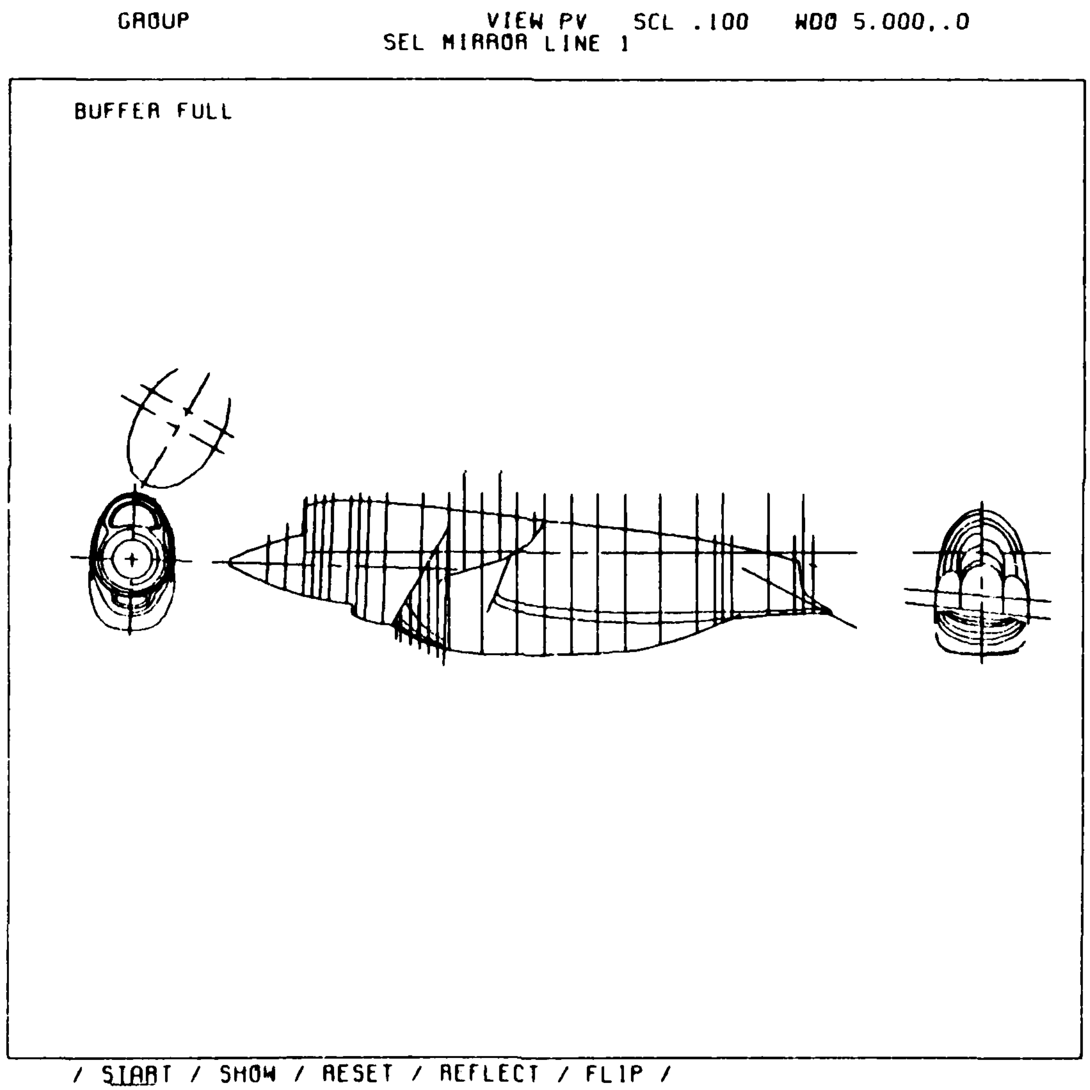

VIEW PV SCL .020 WDO 2.500..0
/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRA /


WINDOW VIEW PV SCL .025 WDO 4.000..0
IND SIZE / KEY SIZE / KEY X.Y.SIZE / SEL ANT TO MOVE / YN SIZE=1
SCL = 4.00000
/ MOVE / TURN / SIZE / RESET / SET / GRID / OVRLY / / 1 / 2 / 3 /

GROUP VIEW PV SCL .025 WDO 1.000,.0
SEL PT / IND PT / YN BACKUP

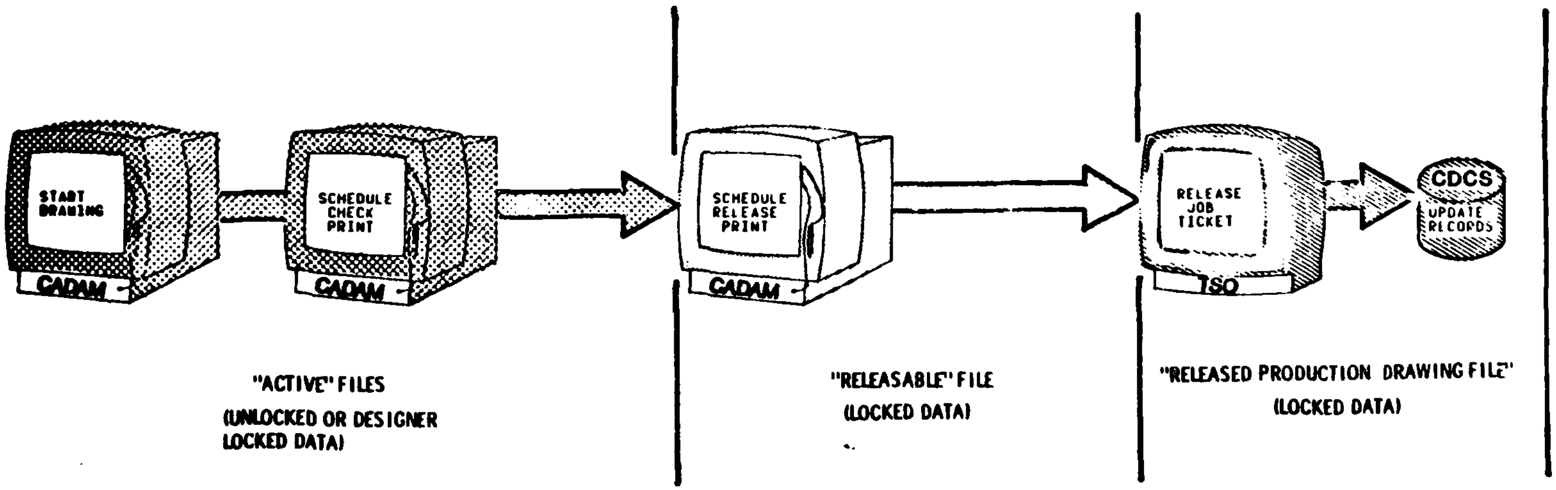


/ TRAP IN / TRAP OUT / RESTORE / MOD TRAP /

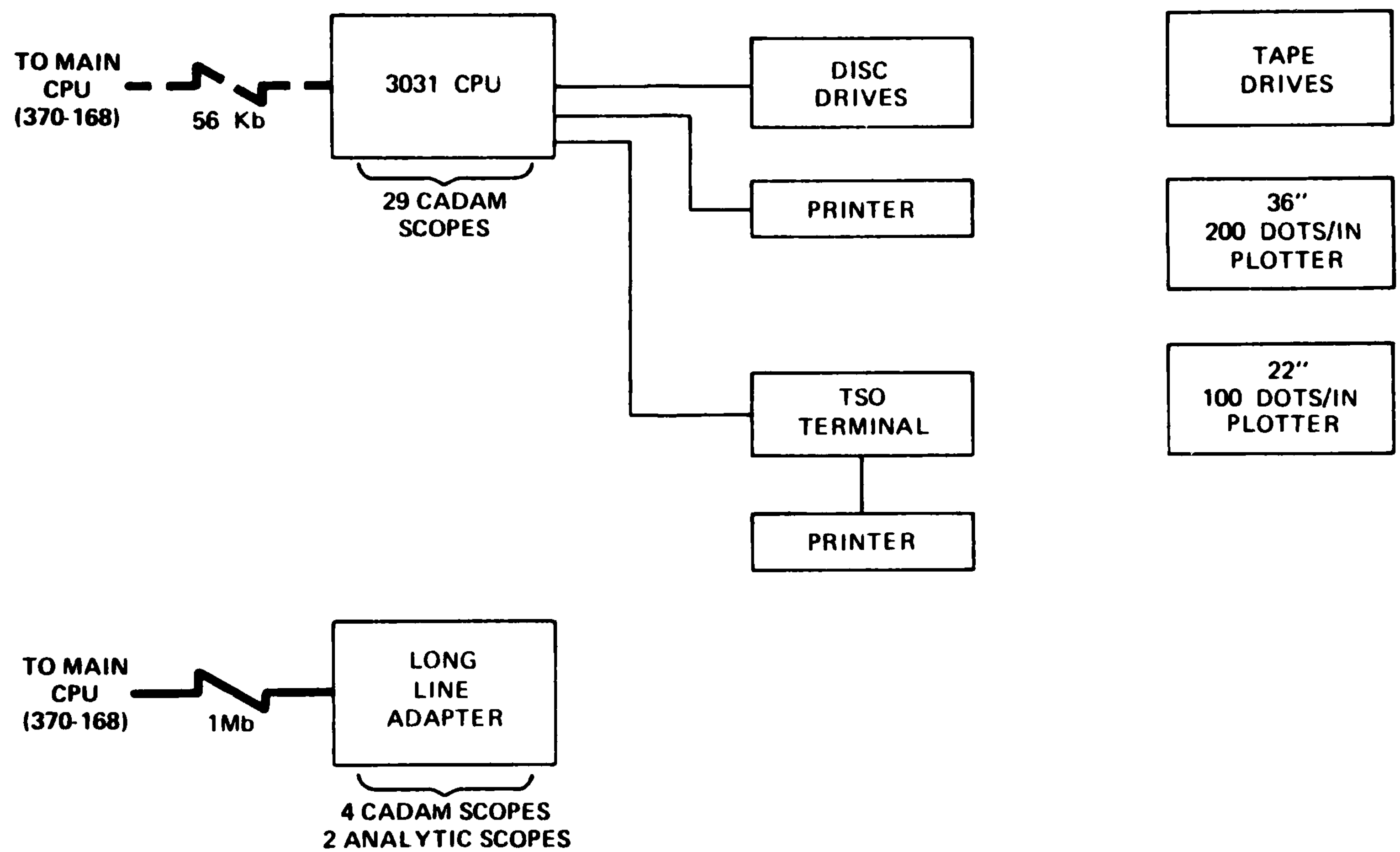

GROUP
VIEW PV SCL .100 WDO 5.000,.0
SEL MIRROR LINE 1
BUFFER FULL
/ START / SHOW / RESET / REFLECT / FLIP /

APPLICATION OF CADAM IN PRODUCTION DESIGN

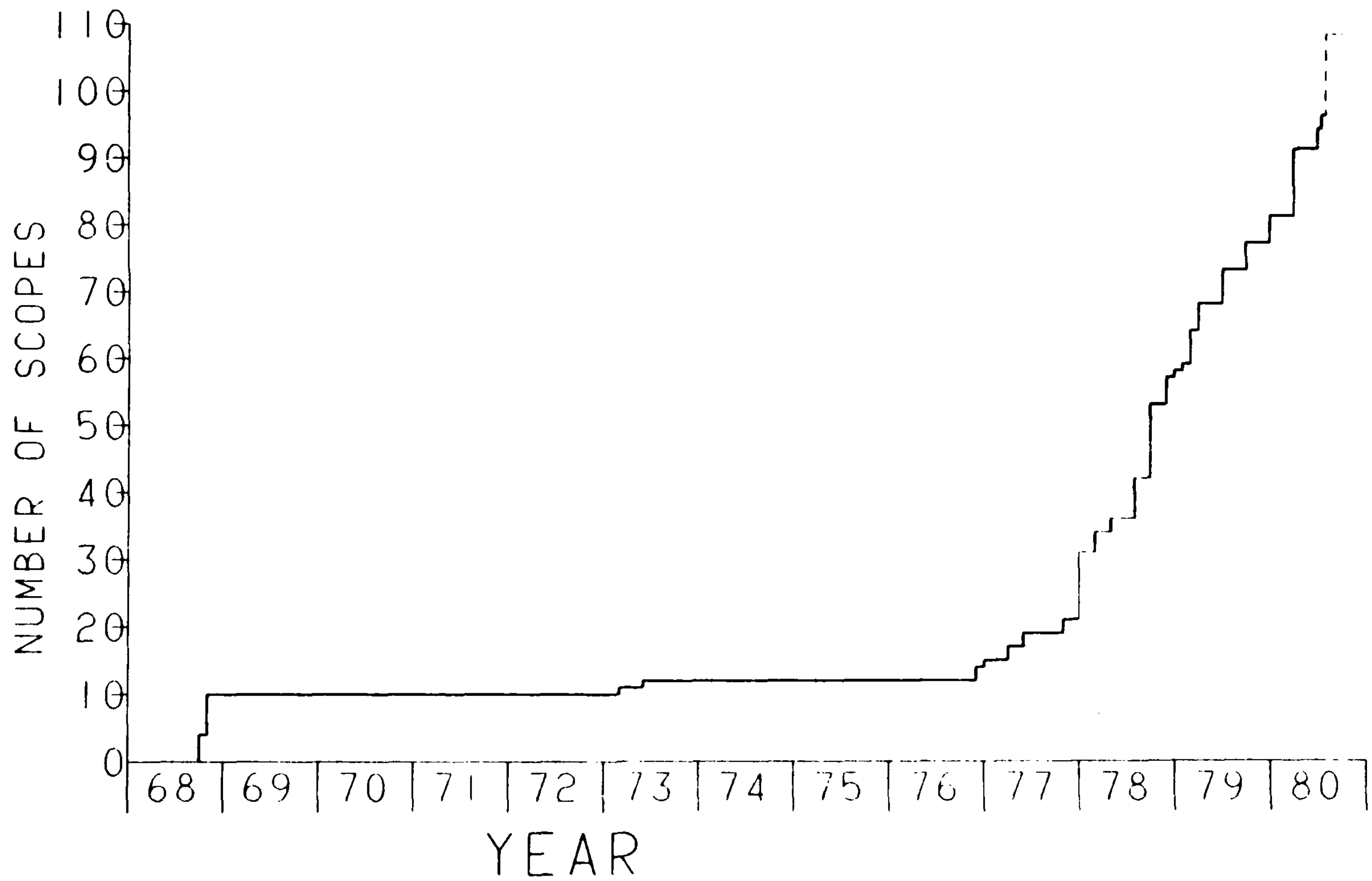
CADAM DRAWING CONTROL SYSTEM



PRODUCTION DESIGN CADAM COMPLEX



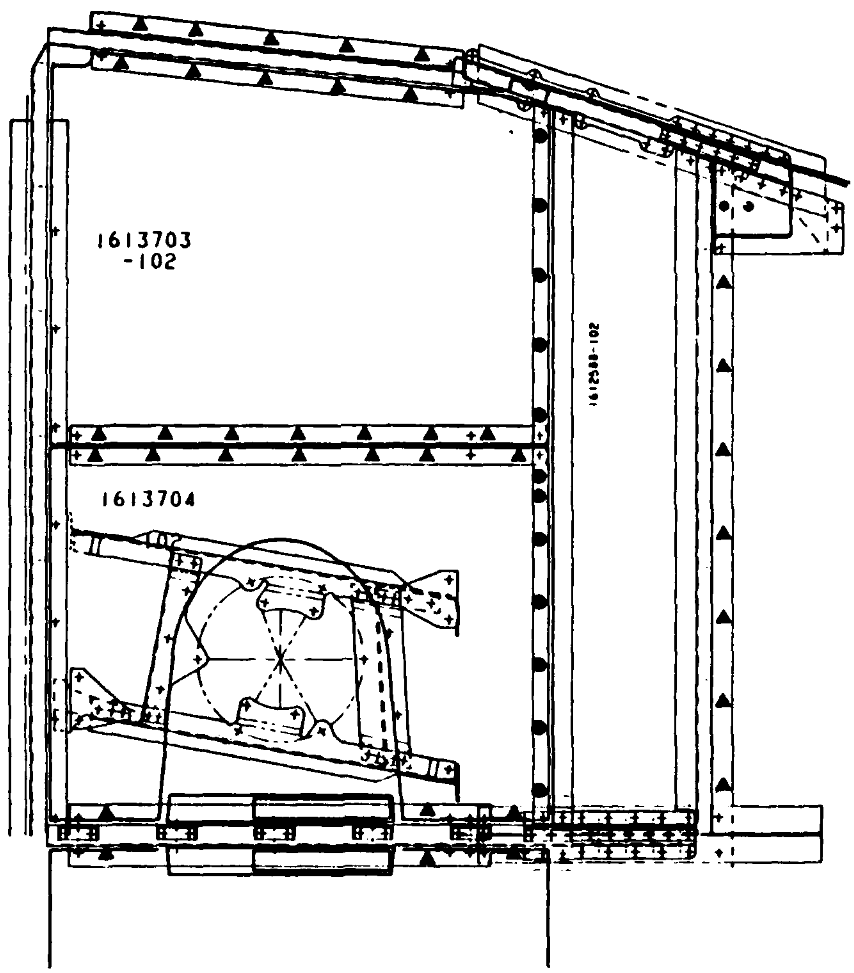
SCOPE GROWTH AT CALAC



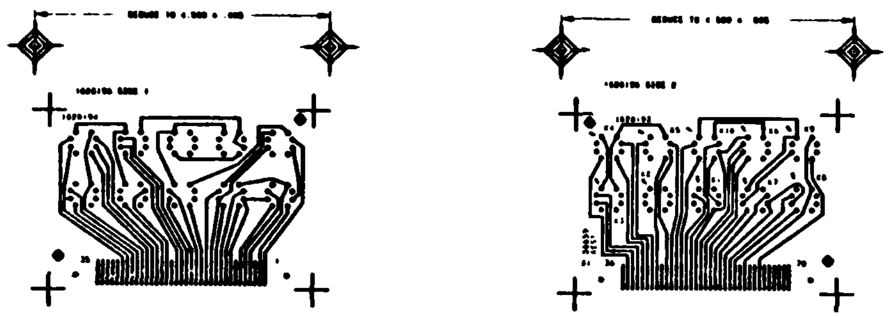
TYPES OF DESIGNS

- AIRFRAME
  - L.E.SLATS
  - FLOOR STRUCTURE
  - RIBS
  - DOOR SEALS
  - FAIRINGS
- INTERIOR ARRANGEMENTS
- INTERIOR DESIGN
  - FLOOR BOARDS
    - CARPETS
  - GALLEYS
  - LAVATORIES
  - CLOSETS
  - CLASS DIVIDERS
- INSTRUMENT PANELS
  - INSTALLATIONS
    - ASSEMBLIES/DETAILS
- MECHANISM LAYOUTS
  - ELEVATOR MECHANISMS
  - LANDING GEARS
  - POWER DRIVE UNITS
  - AILERON FEEDBACK LINKAGE
  - SPOILER INPUT LINKAGE
- HYDRAULIC SCHEMATICS
- ELECTRICAL DESIGN
- ANTENNA INSTALLATIONS
- PAINT & MARKINGS
- STD LIBRARY

FLOORBOARD SUPPORT STRUCTURE



CADAM PREPARED PC BOARD



NOTES:

1. THIS DRAWING WAS PRODUCED BY COMPUTER-GRAPHICS NOT TO BE MANUALLY CHANGED

(2) SEE CDAR FOR SIGNATURES

UNDIMENSIONED DRAWING THIS COPY FOR REFERENCE ONLY

FN	QTY DASH	QTY DASH	QTY DASH	QTY DASH	QTY DASH	QTY DASH	SYM	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	ZONES SH/DES	LTD HIST SCHED	MATL SPEC OR REF DOC	MATL, NOTE SYM OR REF DES	SIZE OR SHAPE	FINAL CONDTN

PARTS LIST

QTY/MHA	QTY/CIC	TOOLG DASH NO	NEXT ASSY	USED ON
			1628194	L-1011

INITIAL APPLICATION (USAGE) DATA - NOT MAINTAINED

EFFECTIVITY DATA: CIC | FROM | THRU | CIC VAR CODE

CONTR LCPF
DATE 4-12-79
PREPARED D. CLARKE
CHECKED
SUPERVISOR P. FOLEY
LOCKHEED APPVL (2)
SCALE 1/1

LOCKHEED-CALIFORNIA COMPANY

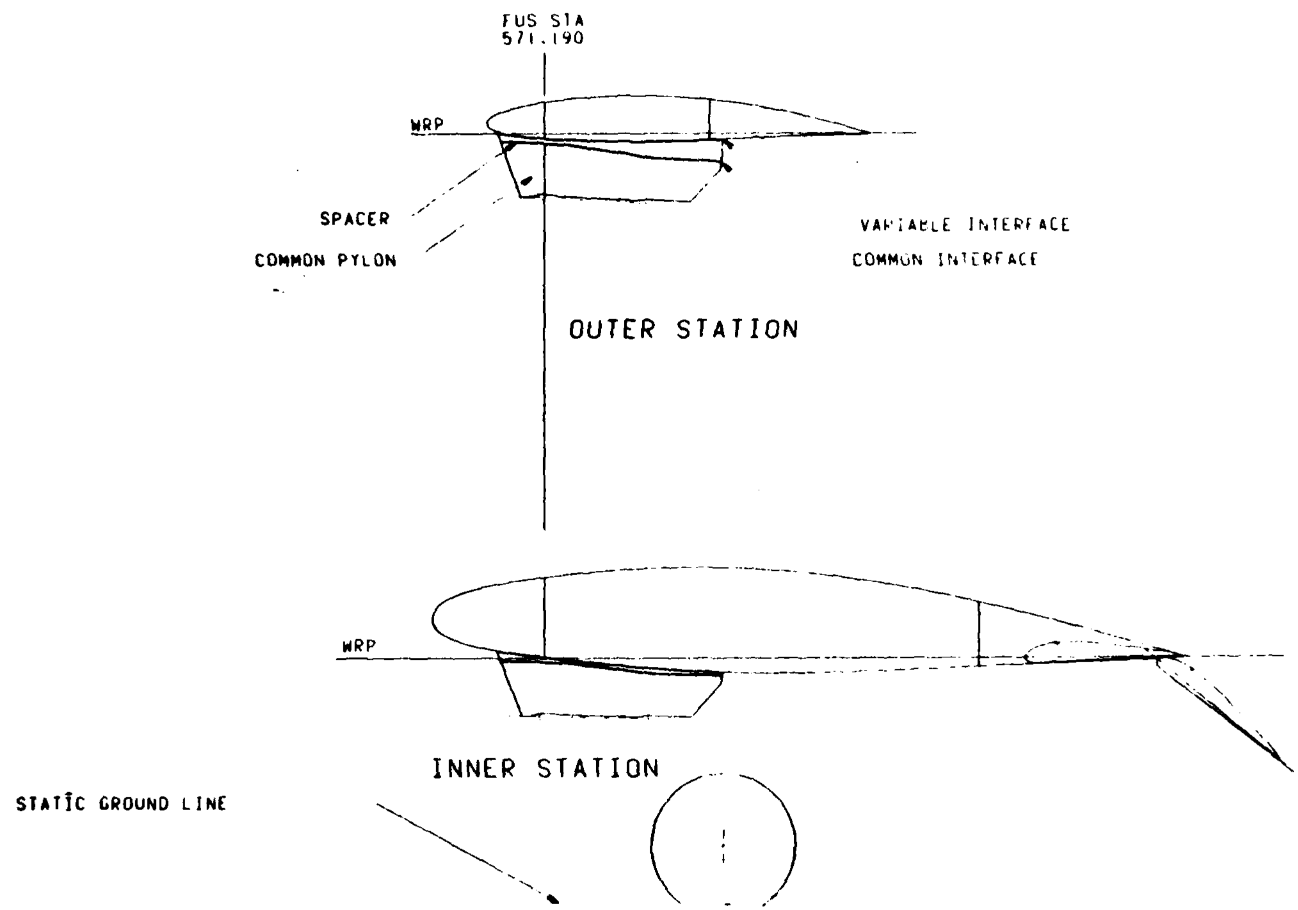
MASTER PATTERN HEADING COUPLER BD 1

SIZE C | FSCM NO. 36659 | DRAWING NO. 1628196

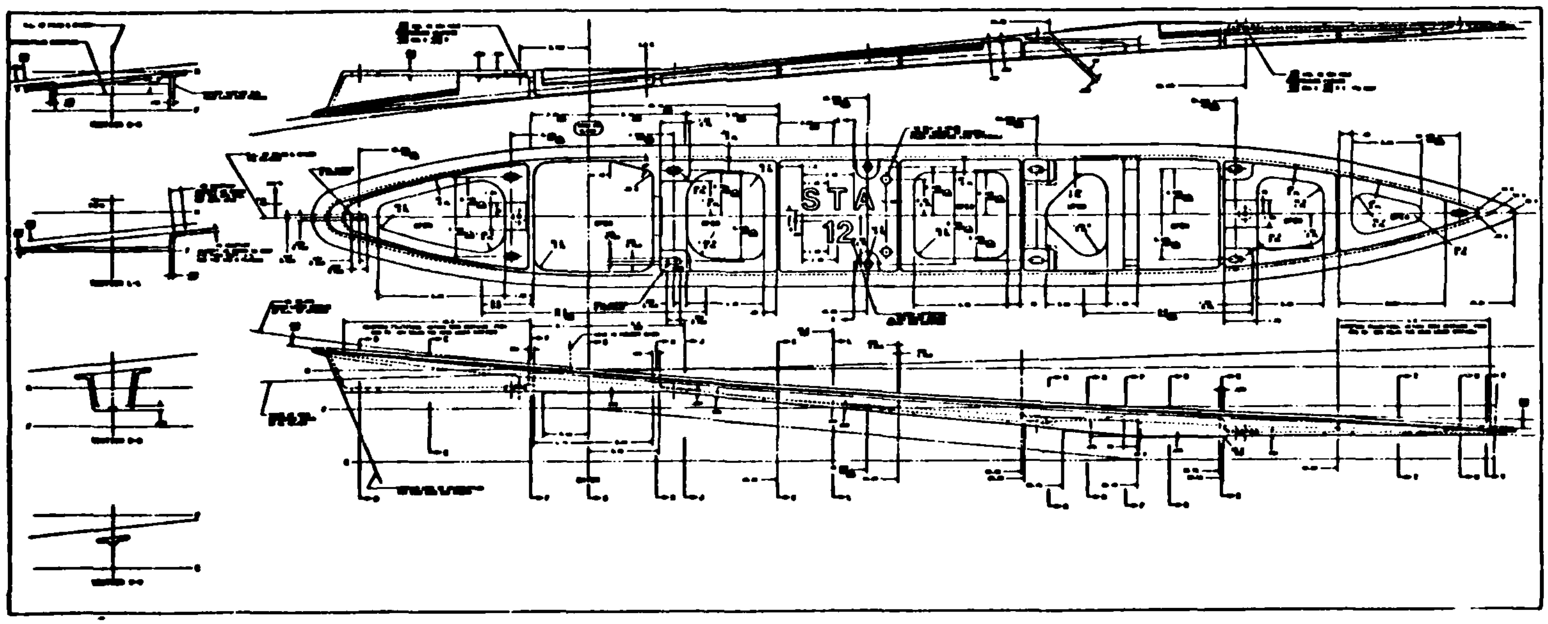
SHEET 1 OF 1

CG 1628196 LVFG0032

PYLON COMMONALITY DESIGN



SPACER



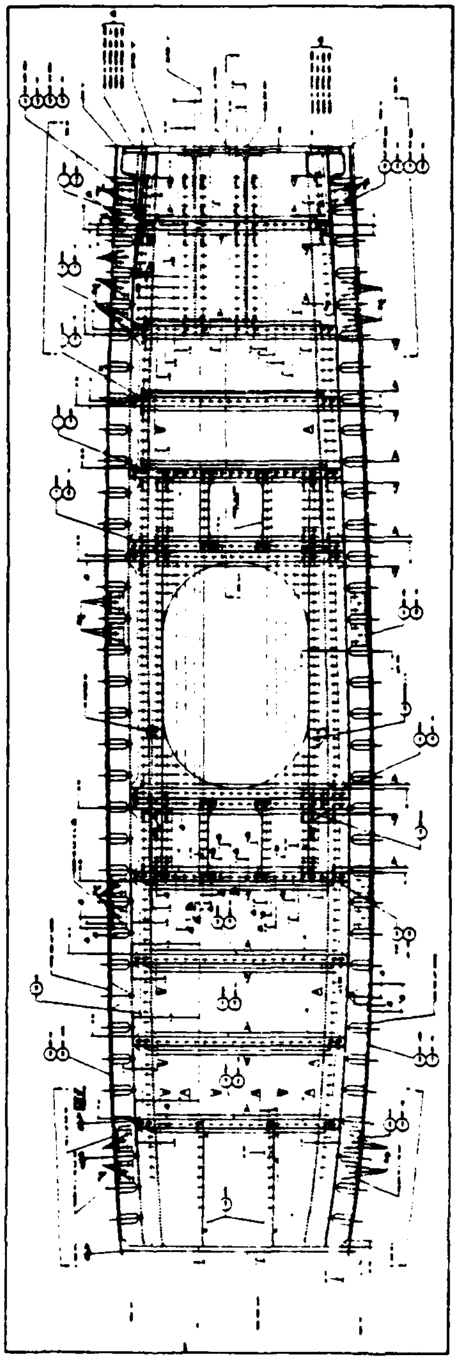
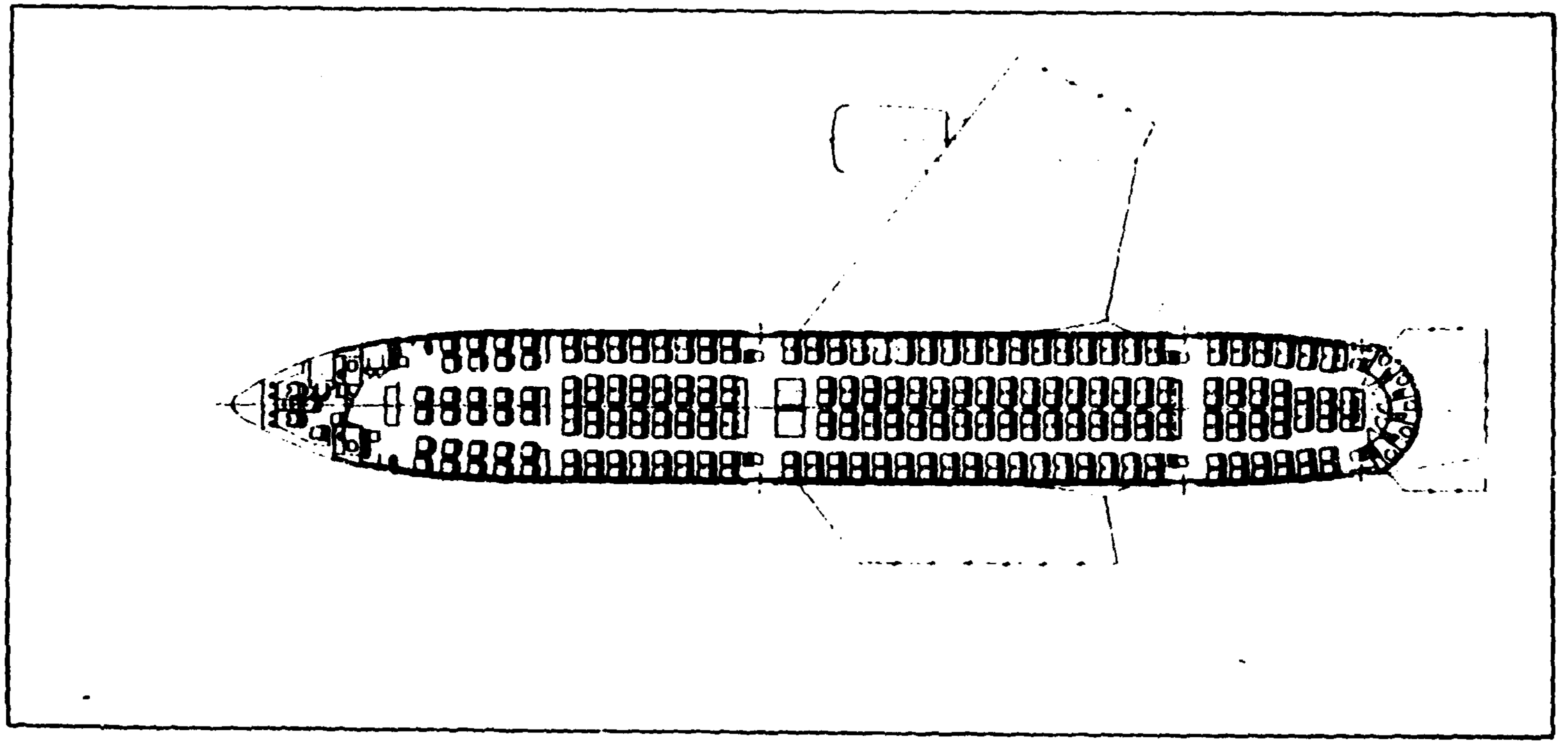
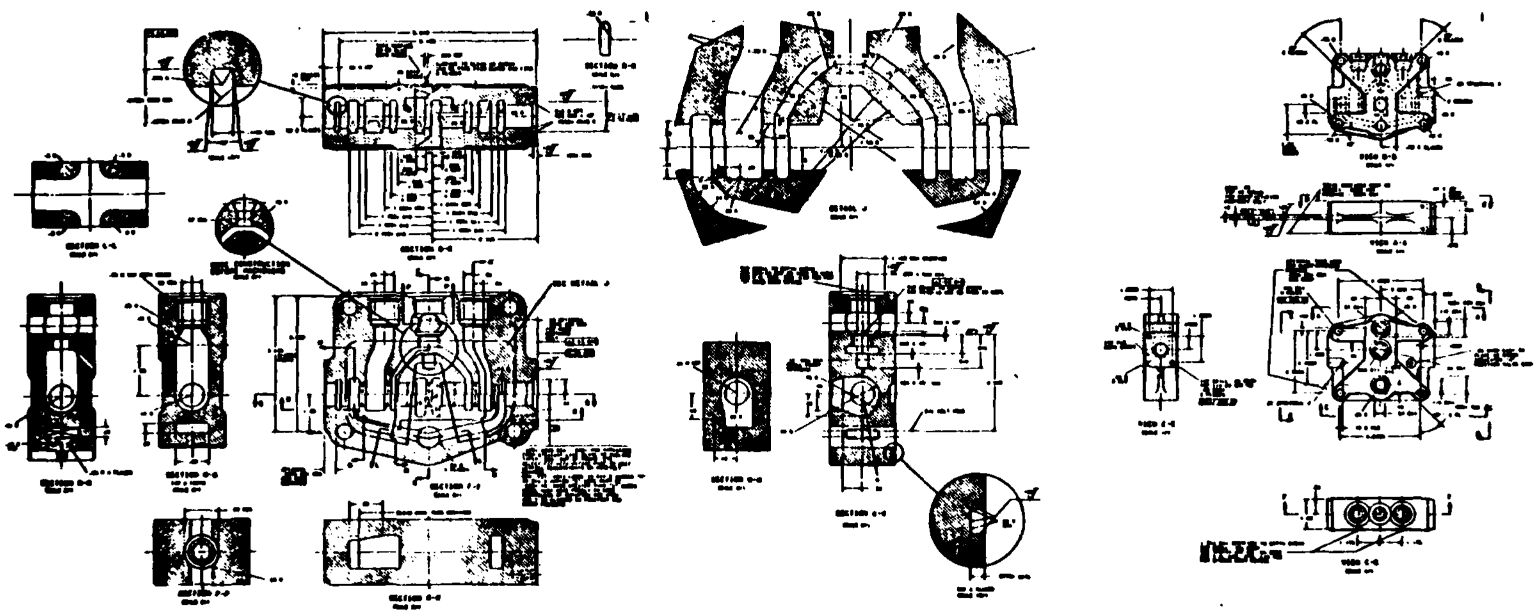


FIGURE 9 L-1011 Horizontal Tail Rib Assembly Produced on the CADAM System

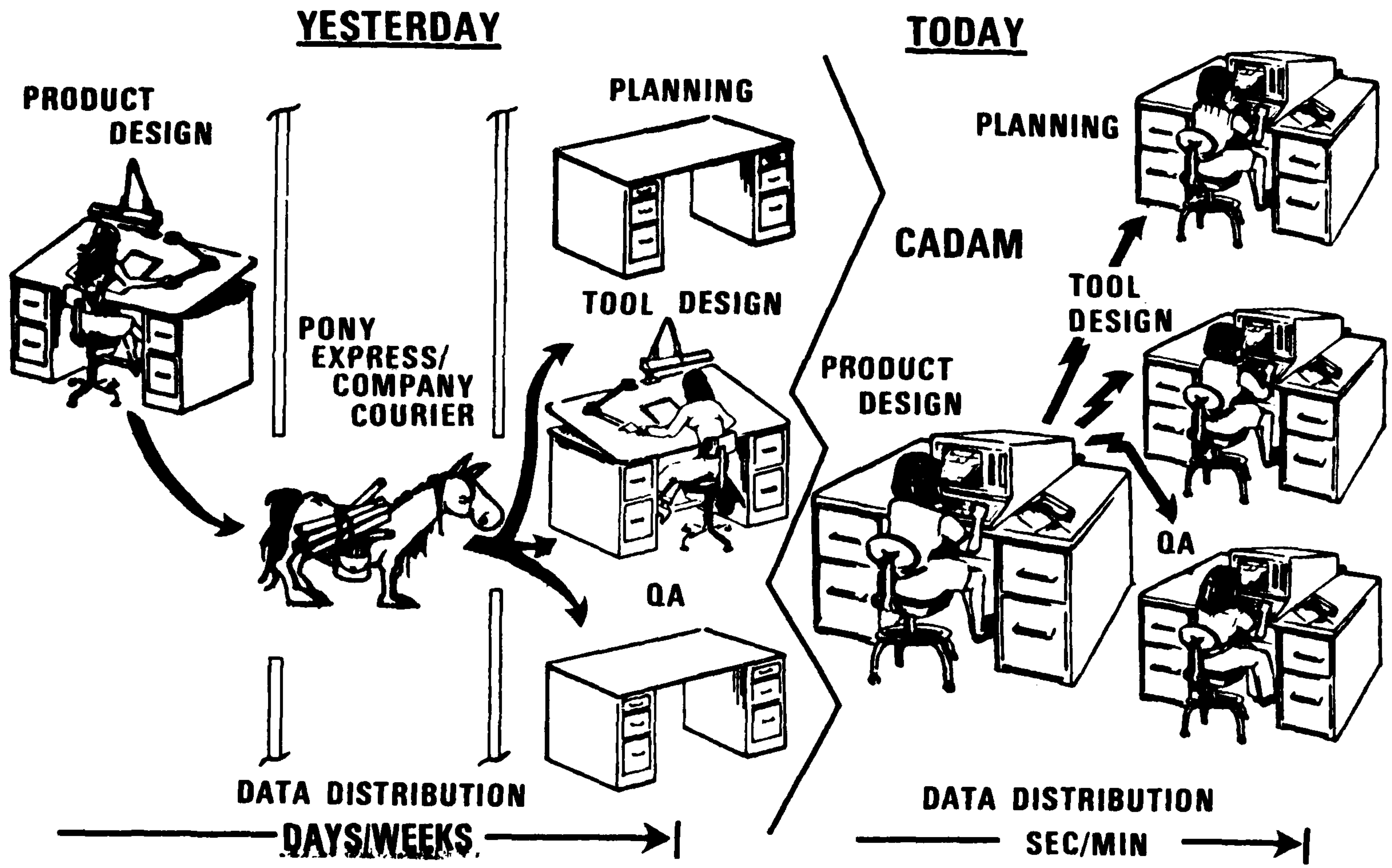
SEATING ARRANGEMENT



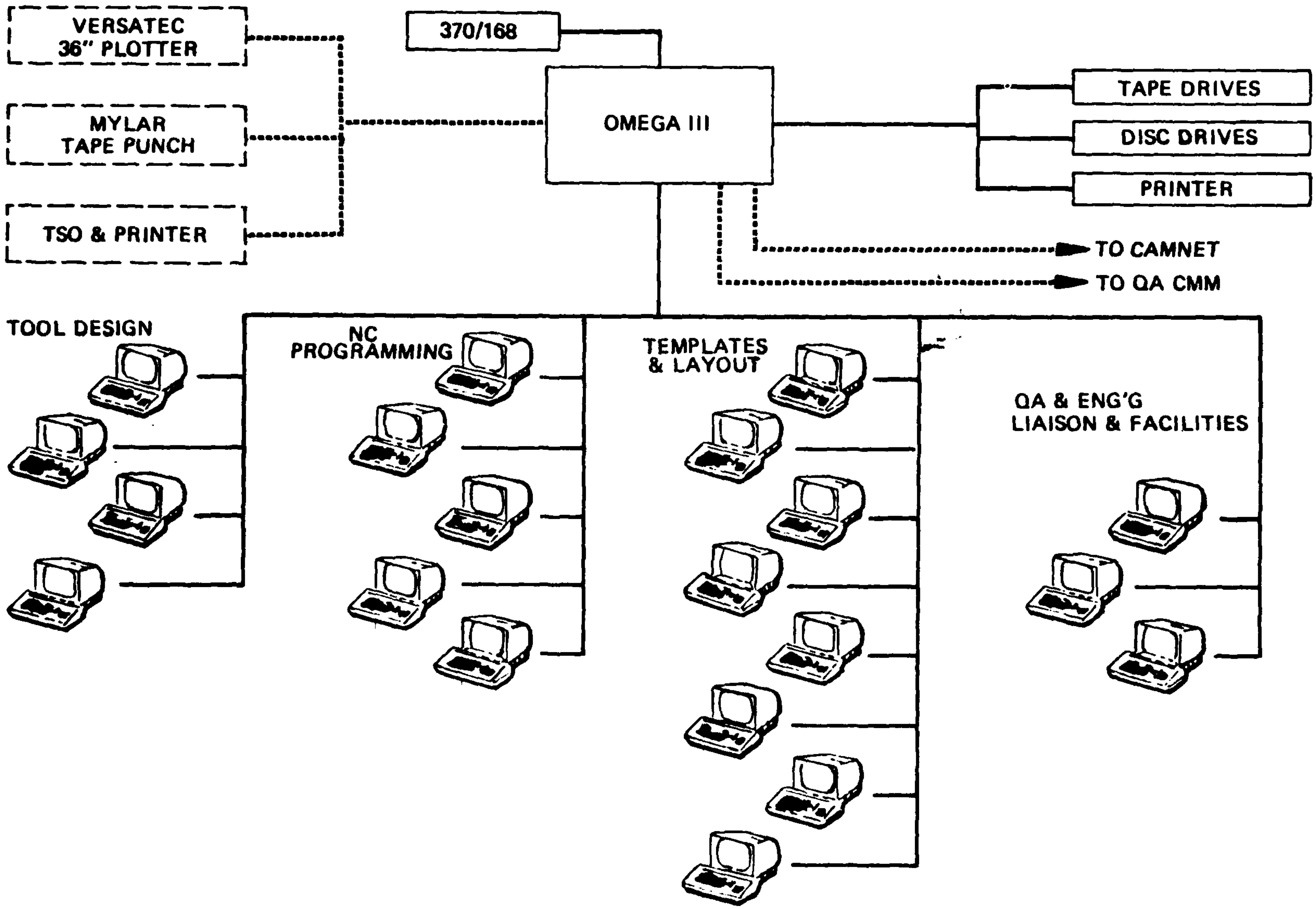
VALVE BODY



APPLICATION OF CADAM IN MANUFACTURING


YESTERDAY
PRODUCT DESIGN
PONY EXPRESS/ COMPANY COURIER
PLANNING
TOOL DESIGN
QA
DATA DISTRIBUTION
DAYS/WEEKS
TODAY
CADAM
PLANNING
TOOL DESIGN
PRODUCT DESIGN
QA
DATA DISTRIBUTION
SEC/MIN

CADAM MANUFACTURING/QA FACILITY

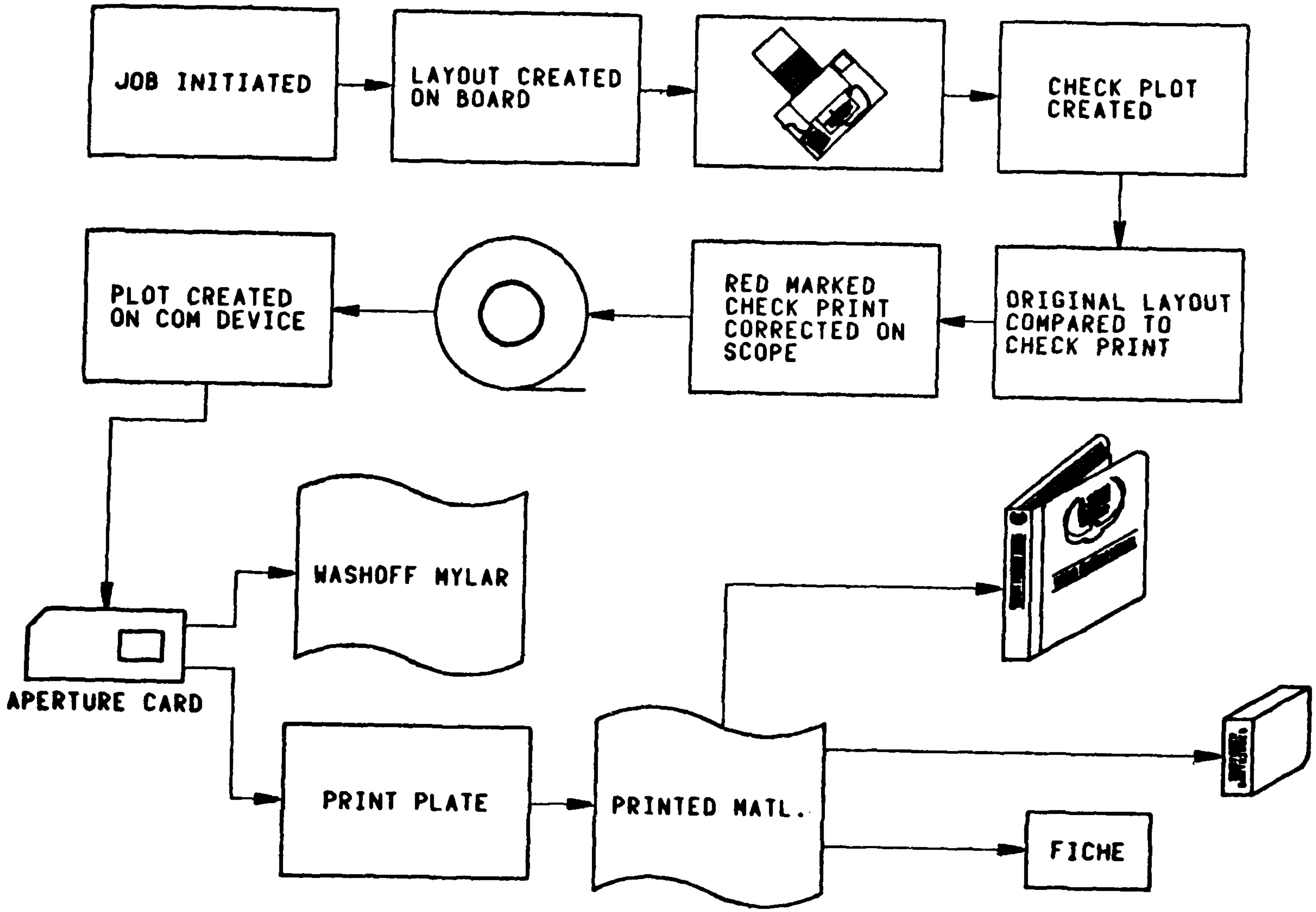


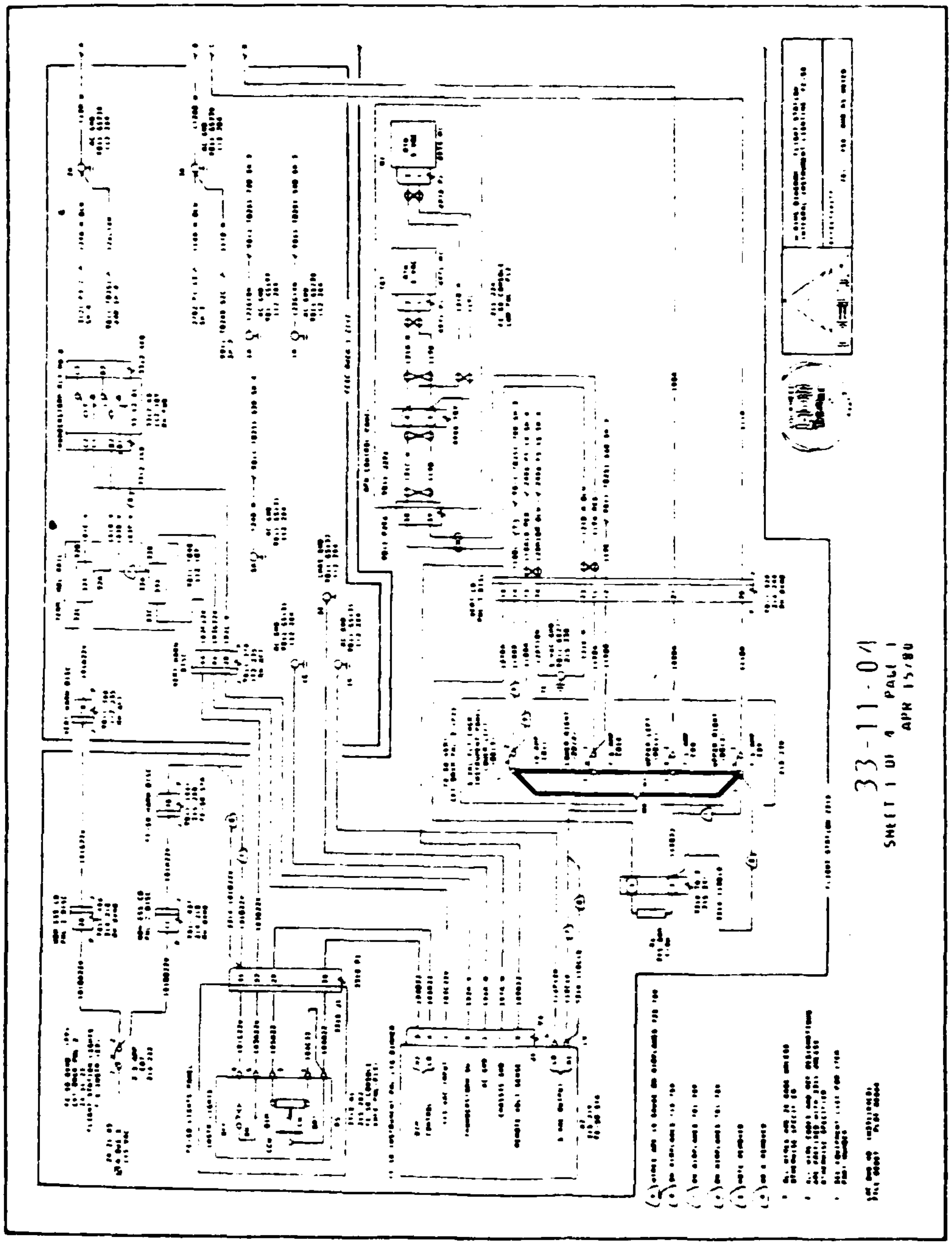
APPLICATION OF CADAM IN PRODUCT SUPPORT

L 1011 WIRING DIAGRAM MANUAL

- WIRING DIAGRAMS DOCUMENT THE ELECTRICAL/ELECTRONIC WIRING IN THE L-1011
- WIRING DIGRAMS ARE USED TO TROUBLE SHOOT INOPERATIVE SYSTEMS
- WIRING DIAGRAMS ARE USED TO DESIGN MODIFICATIONS TO SYSTEMS.

WDM GROUP ACTIVITY FLOW CHART





WIRING DIAGRAM
FIGURE 1.102

VIEW PV SCL 1.000 WD0 1.000,.0

CADAM

ADVANTAGES

- REDUCED COSTS
- REDUCED MAN-HOURS
- SHORTER TIME SPAN
- LESS ERRORS
- GREATER ACCURACY
- CAPABILITY TO PERFORM MORE DESIGN ITERATIONS
- COMMON DATA BASE
- EASIER AND FASTER REDESIGN
- ONLY SOLUTION TO SOME JOBS

/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

VIEW PV   SCL 1.000   WDO 1.000,.0

CADAM

PROBLEMS

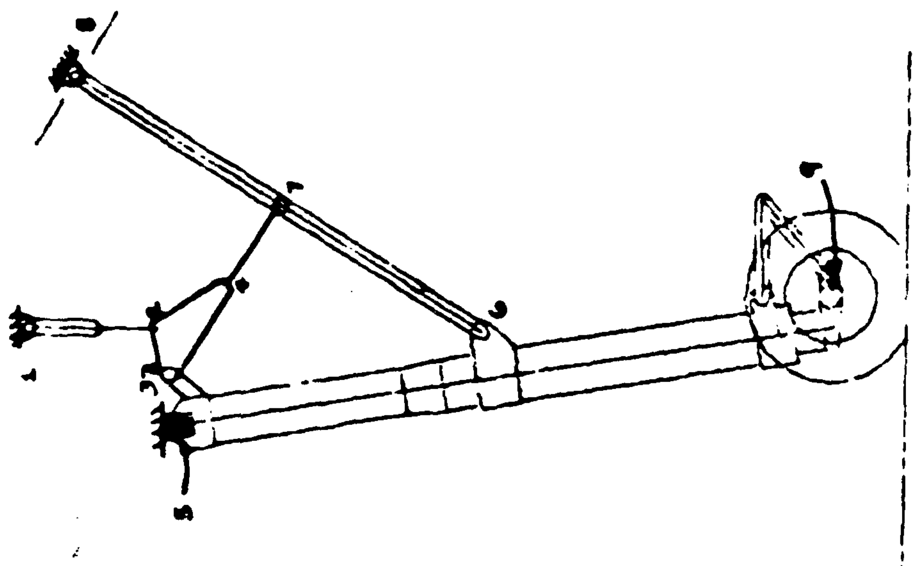
- HARD TO TEACH OLD DOGS NEW TRICKS
- CAPITAL EXPENDITURES
- SCOPE ACCESS
- BUFFER FULL

/ PLOT1 / PLOT3 / FILM / WINDOW / NEW FRAME / OLD FRAME / ELECTRO /

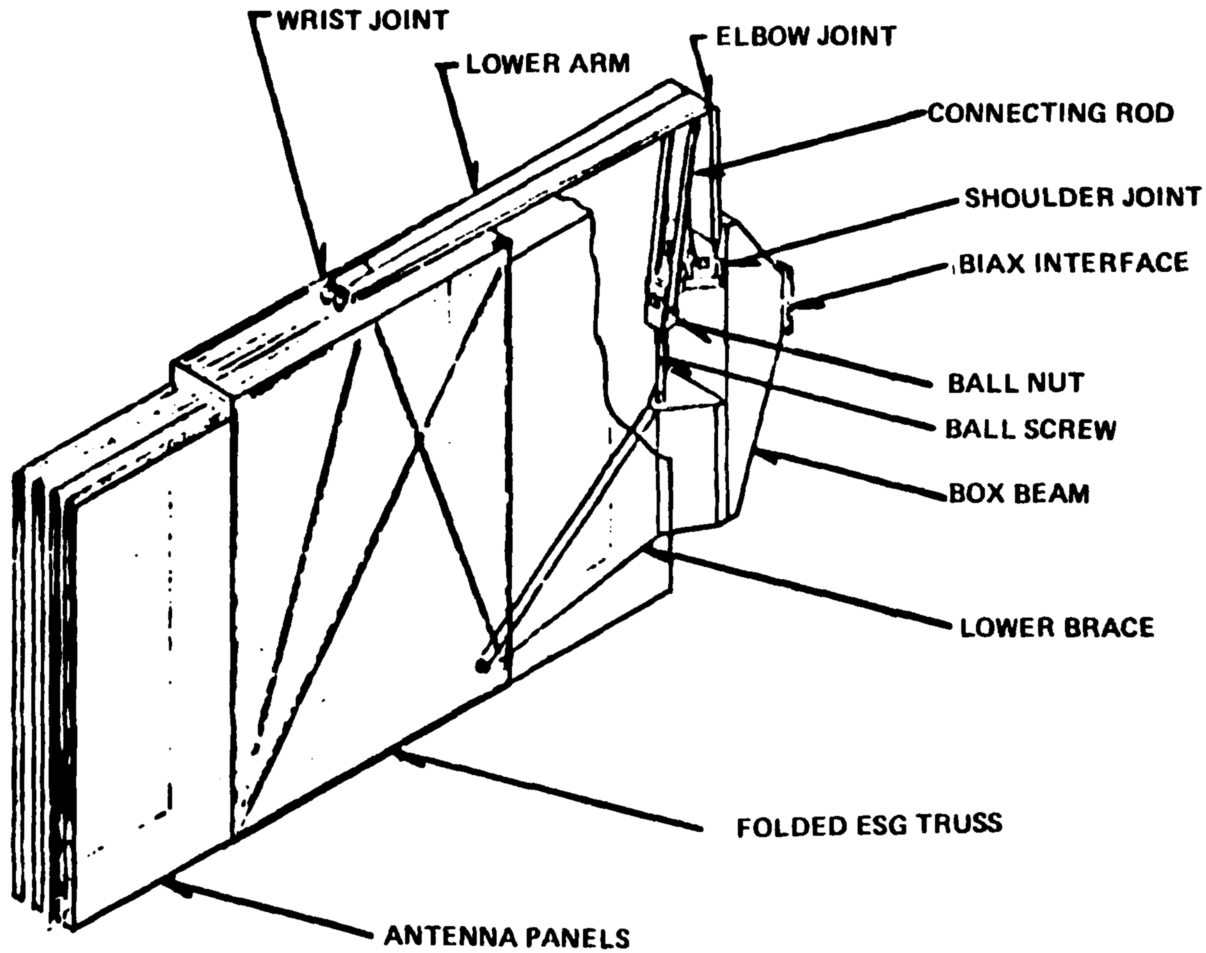
MECHANISMS

APPLICATIONS

- AIRCRAFT
  - LANDING GEARS
  - CONTROL LINKAGES
  - CONTROL VALVES
  - DOOR LATCHING MECHANISMS
  - FLAP TRACKS
  - AIR STAIRS
- SPACECRAFT
  - SOLAR PANELS
  - ANTENNAS
  - SPACE SHUTTLE ARM

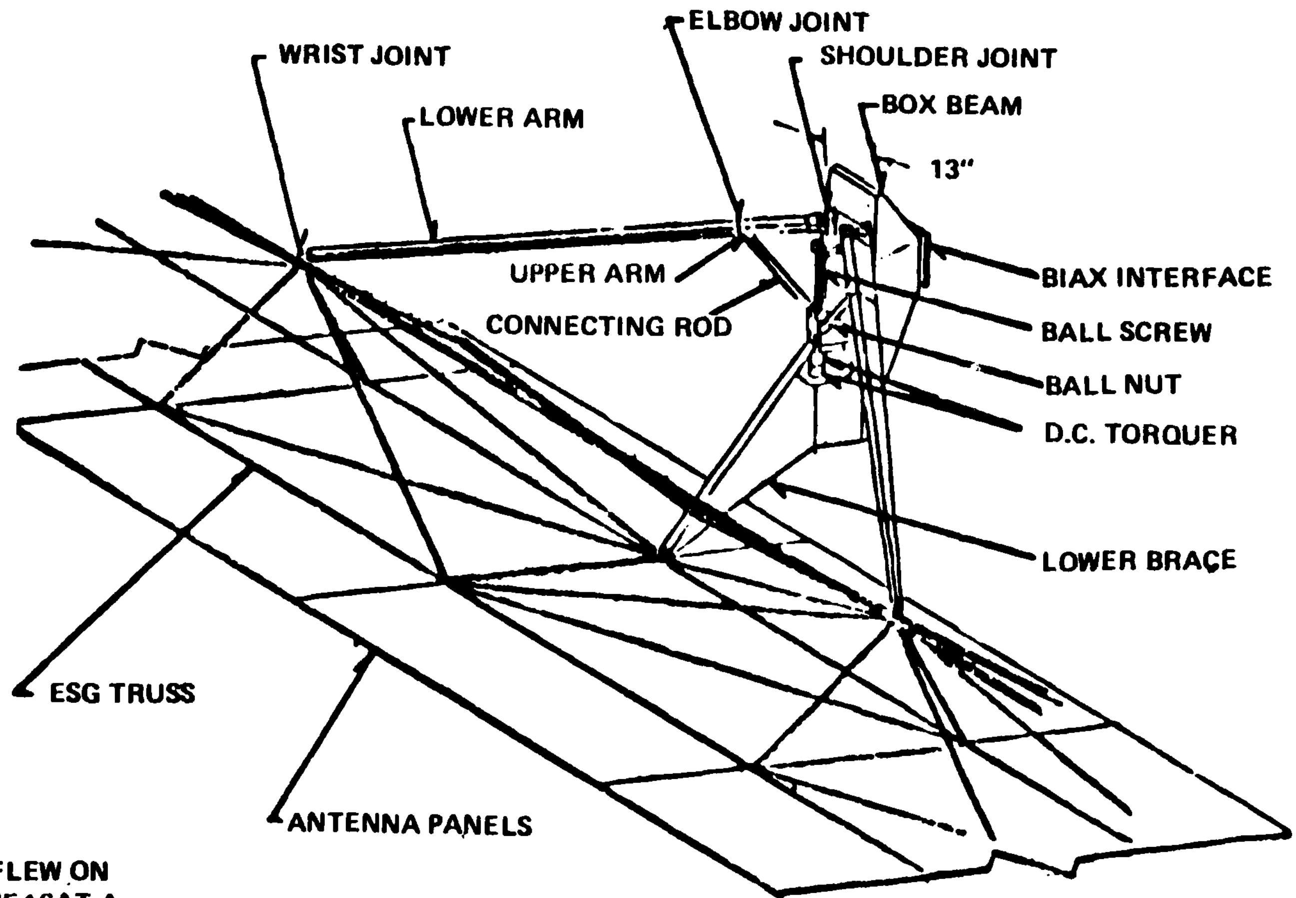


STOWED EXTENDIBLE SUPPORT STRUCTURE



DEPLOYED EXTENDIBLE SUPPORT STRUCTURE

SYNTHETIC APATURE RADAR (SAR)



FLEW ON
SEASAT A

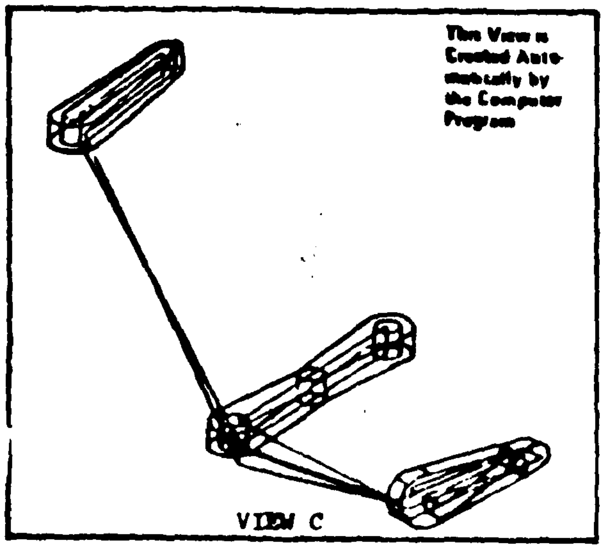
MECHANISM DESIGN

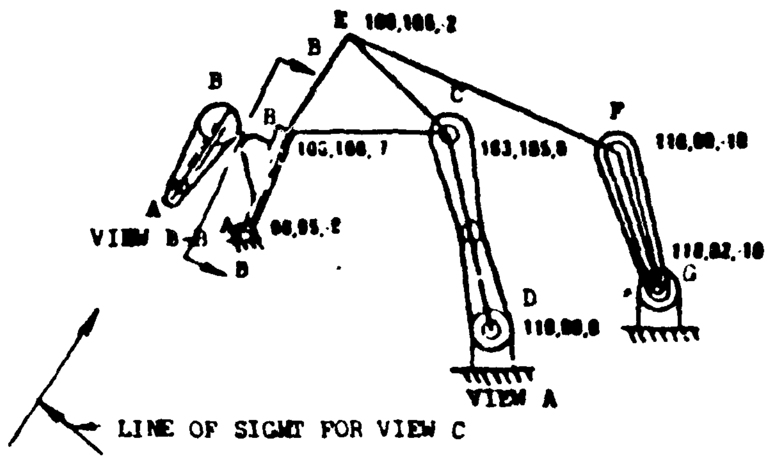
- POSITION - VELOCITY - ACCELERATION ANALYSES
- STRUCTURAL LOADS AND DEFLECTION ANALYSIS
- MECHANICAL ADVANTAGE
- CLEARANCE PROBLEMS

PRESENT CAPABILITIES

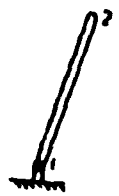
- INTEGRATED IN CADAM
- 3-D MOTION SIMULATION
- 16 BASIC UNITS
- LARGE MODEL CAPABILITY
- TABULAR AND GRAPHICAL OUTPUT

THREE-DIMENSIONAL MECHANISM



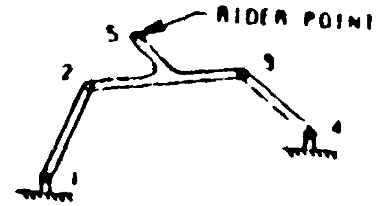


MOTION SIMULATION



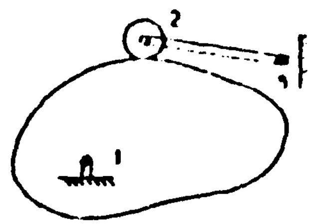
LINK

FOUR BAR

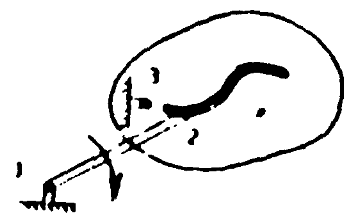


FOURBAR WITH RIDER POINT

FOURBAR DRIVEN BY LINK
THROUGH RIDER POINT

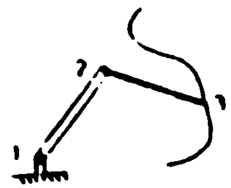


CAM

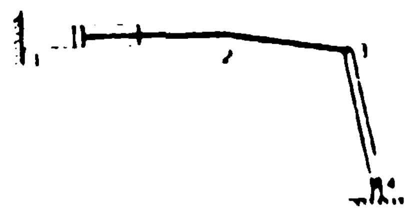


SLOT

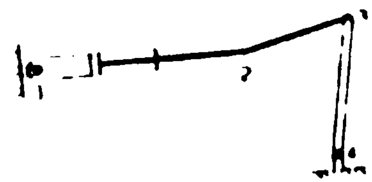
MOTION SIMULATION



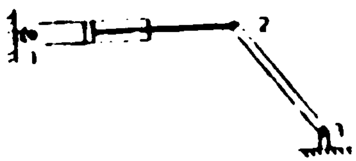
TRACK



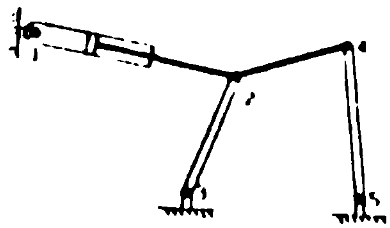
FIXED END ACTUATOR DRIVING LINK



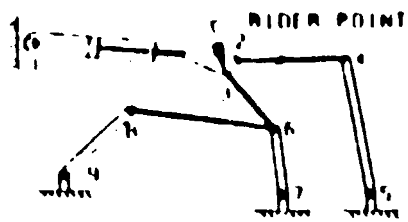
ACTUATOR DRIVING LINK THROUGH INTERMEDIATE LINK



ACTUATOR DRIVING LINK

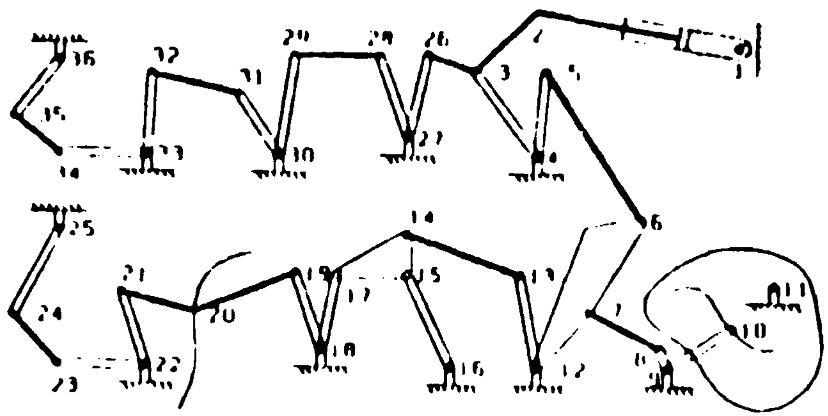


ACTUATOR DRIVING A FOURBAR UNIT



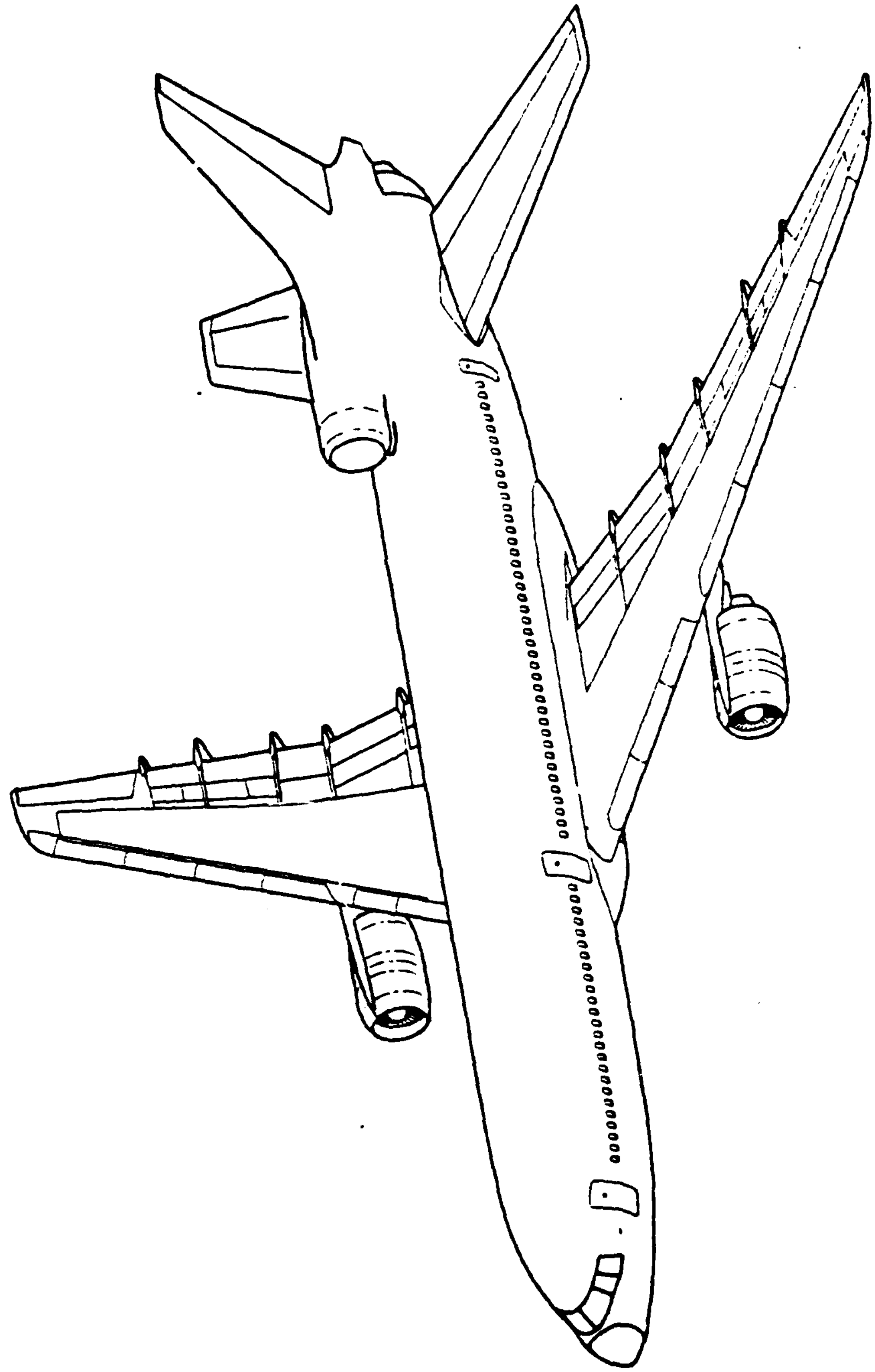
ACTUATOR DRIVING UNIT THROUGH RIDER POINT

MOTION SIMULATION



LARGE MODELS

SURFACES



SURFACES

AIRSWEPT SURFACE DEFINITION

LOFTING

SURFACE LOFTING

SURFACE DESIGN

LOFTING APPLICATION

- INITIATED IN PRELIMINARY DESIGN
- EVOLVES AND MATURES WITH PROJECT
- RESULTS IN SURFACE SHAPE DEFINITION
- USED BY: PRELIMINARY DESIGN
  PRODUCTION
  TOOLING AND FABRICATION

LOFTING PROBLEM

DEFINE A SMOOTH SURFACE WITH LUMPS

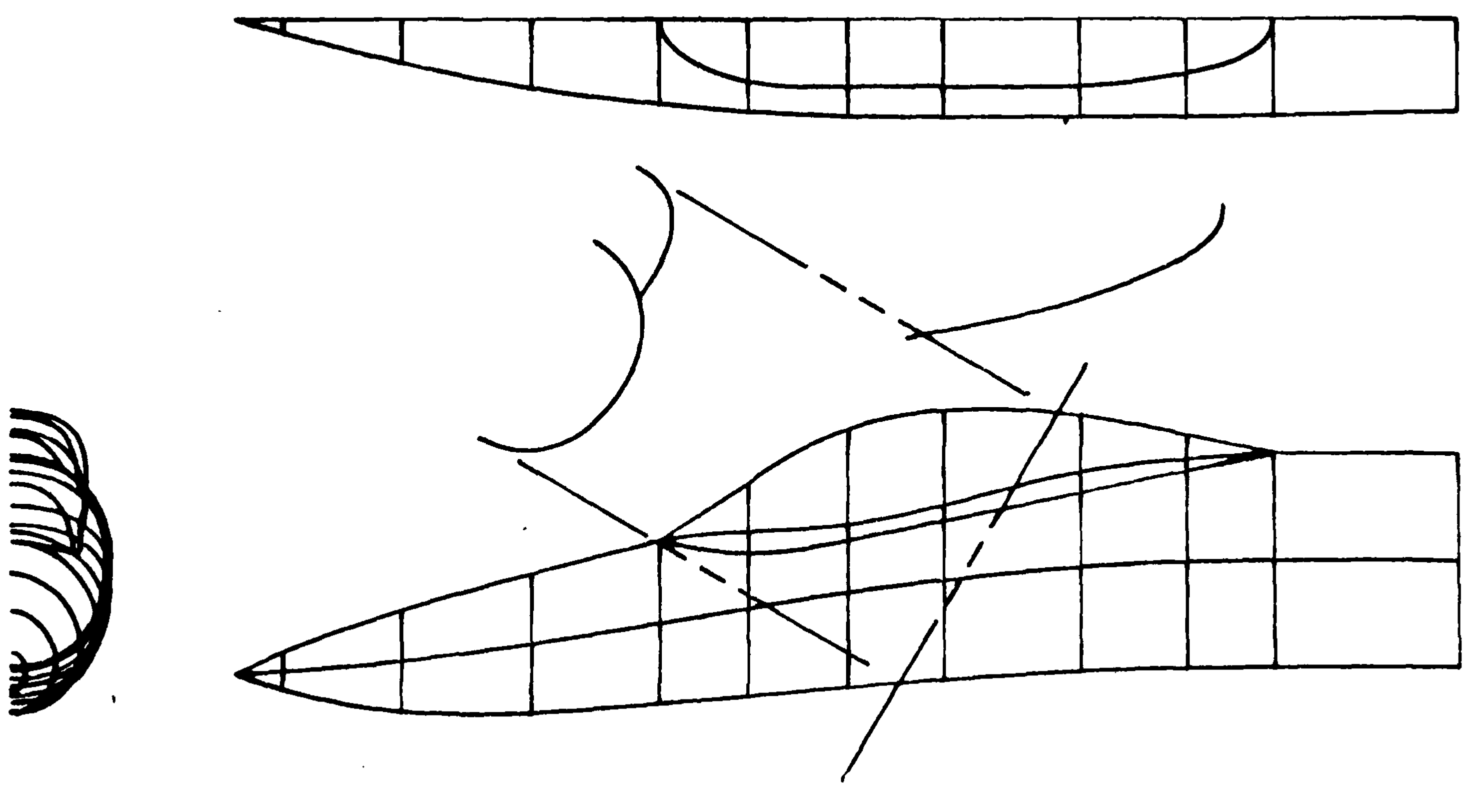
CONSTRAINTS:

- ENCLOSE: STRUCTURE, CREW, AVIONICS, ETC.
- MEET AERODYNAMIC REQUIREMENTS
  - AREA PROGRESSION
  - SHAPE
  - SMOOTHNESS
  - FAIRNESS

LOFTING METHODS

- MANUAL - HAYLOFT
- COMPUTER AIDED
  - MESH OF POINTS
  - PATCHES
  - NET OF CURVES

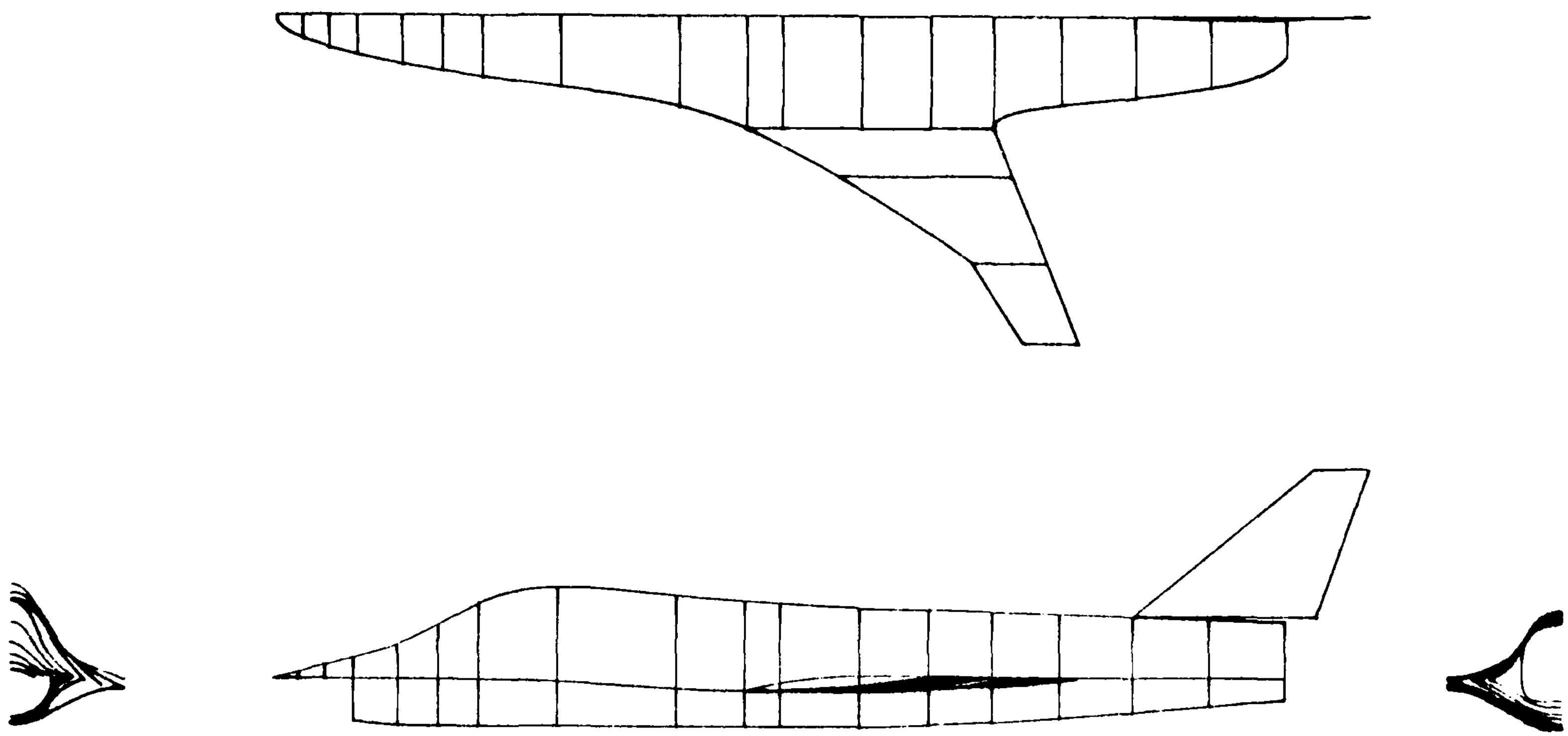
DESIGN CURVES - SURFACE RESULTS



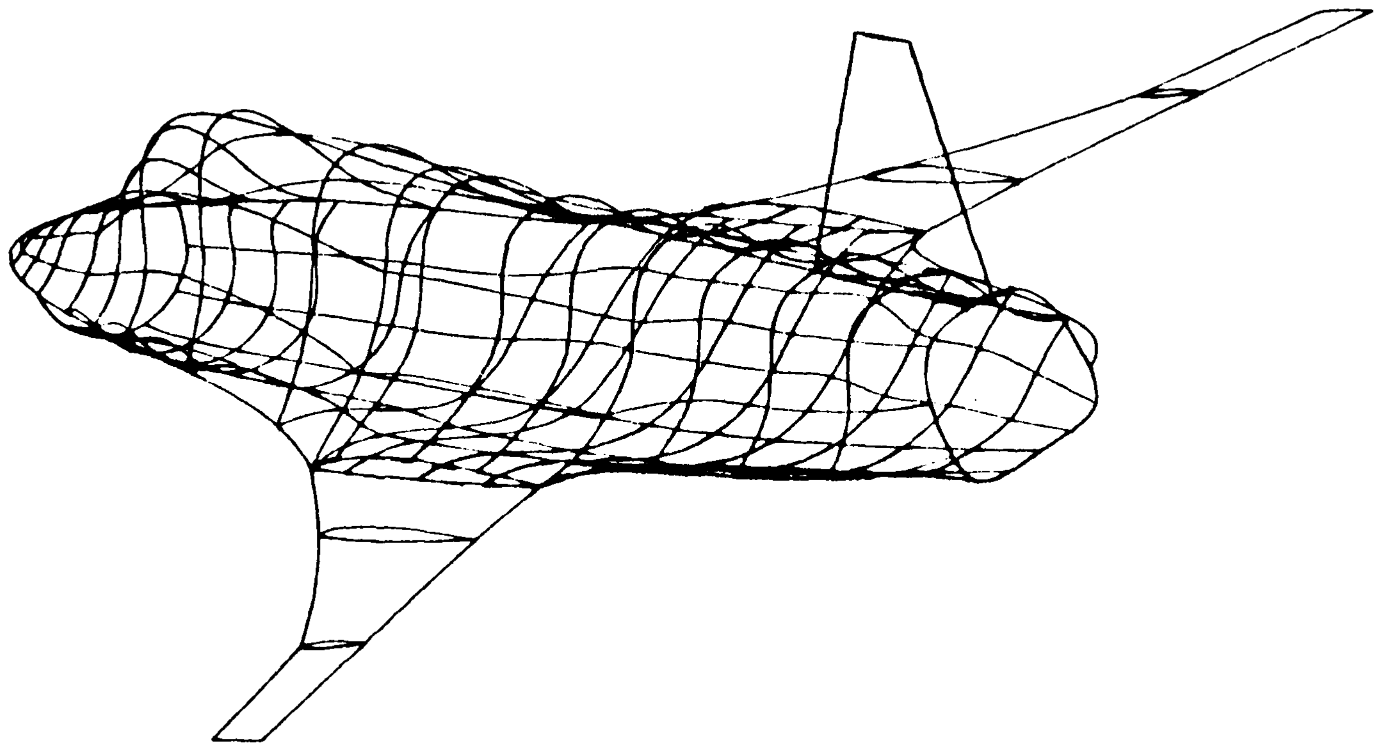
TIME COMPARISON

OLD SYSTEM	TASK	NEW SYSTEM
1000 HRS. EST. 3 MONTHS SPAN	RADOME	20 HRS. ACTUAL 1 WEEK SPAN
900 HRS. EST. 3 MONTHS SPAN	WING FILLET	6 HRS. ACTUAL 1 DAY SPAN
80 HRS. EST. 1 WEEK SPAN	HORIZONTAL TAIL	2 HRS. PD ACTUAL 0 SPAN
500 HRS. EST. 2 MONTH SPAN	HORIZONTAL TAIL TIP	8 HRS. ACTUAL 2 DAYS SPAN

DESIGN WITH 3-VIEW

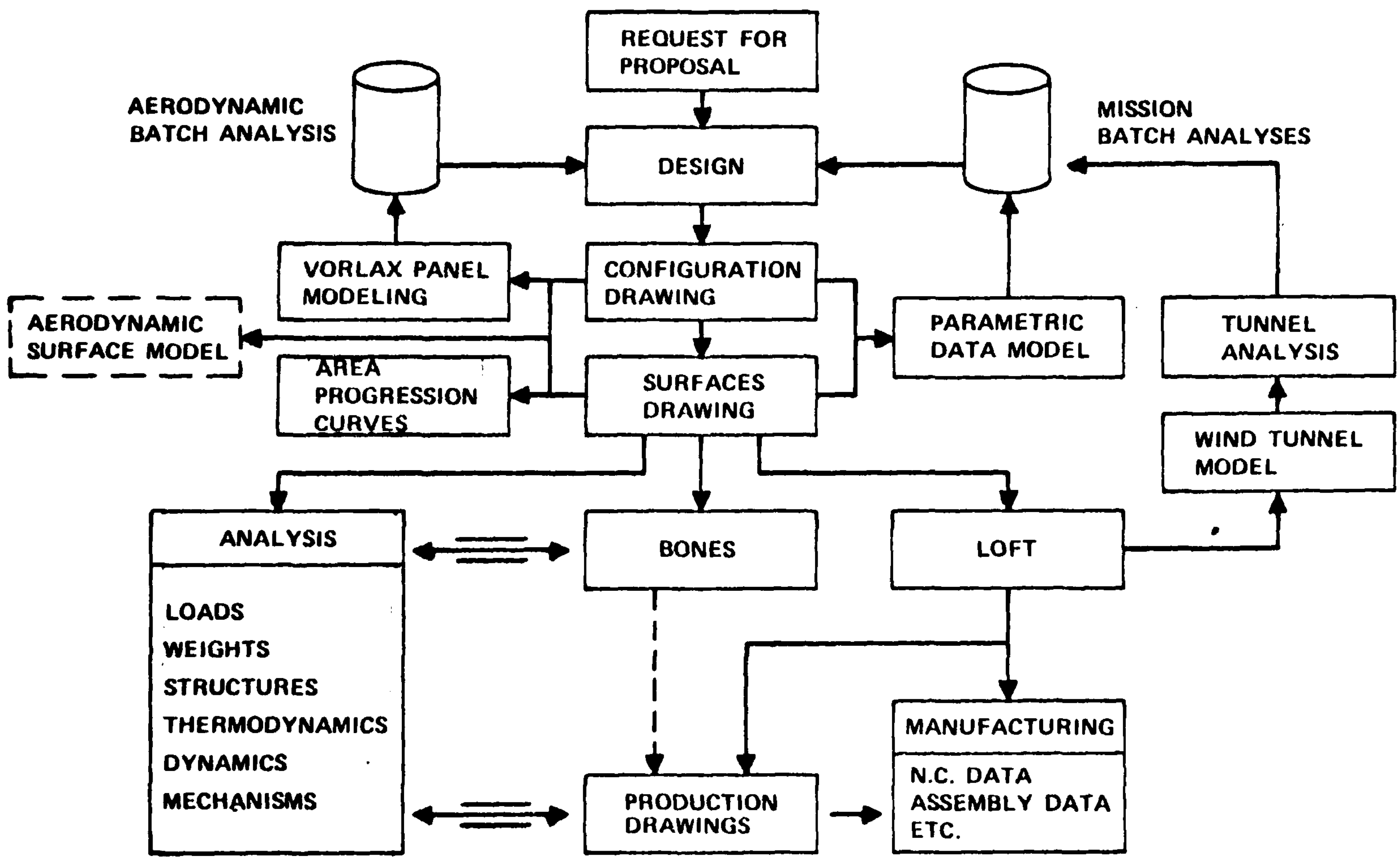


40 HOURS FROM ROUGH LAYOUT



ANALYSIS MODELING

DESIGN PROCESS



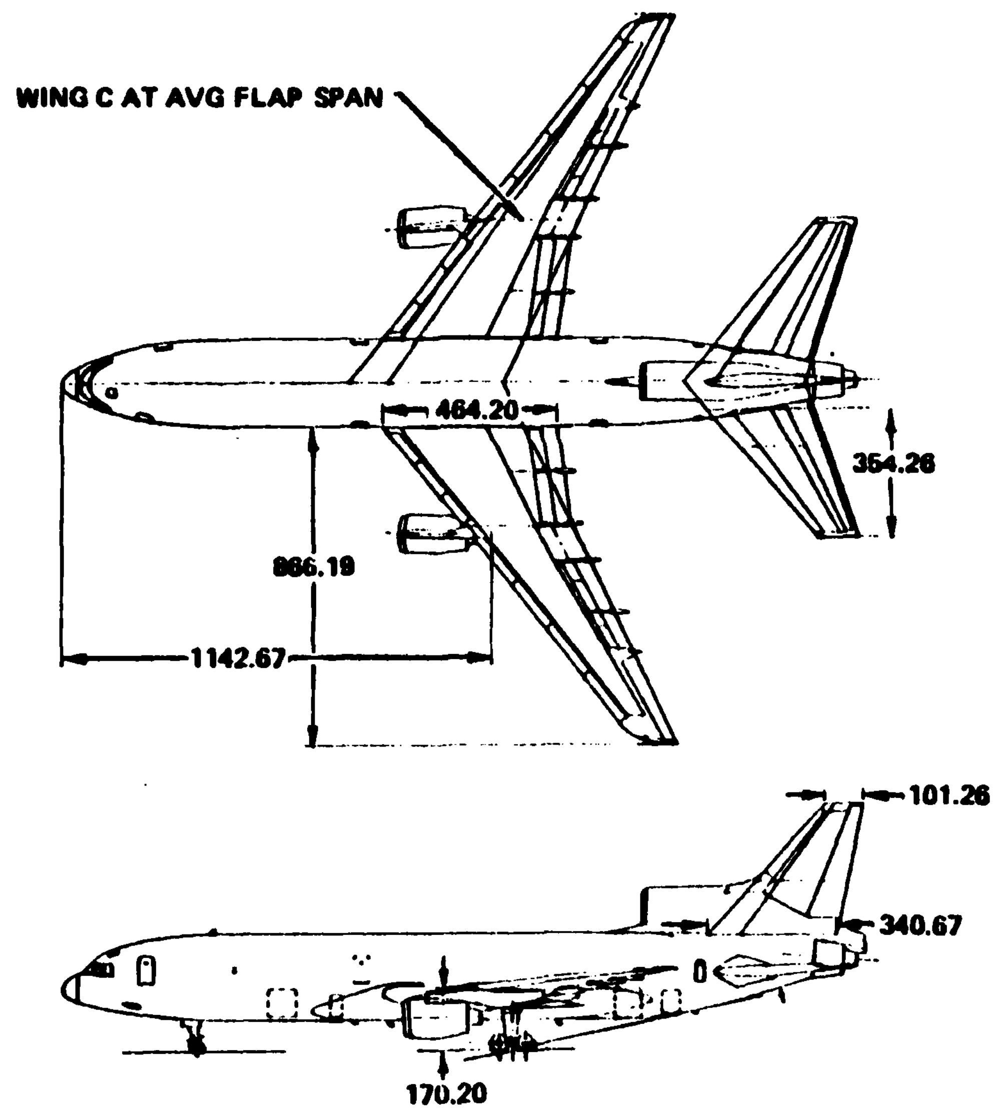
INTRODUCTION

- EXISTING DATA BASE
- EXTRACTION OF DATA
- TECHNIQUES
  - REAL TIME
  - BATCH

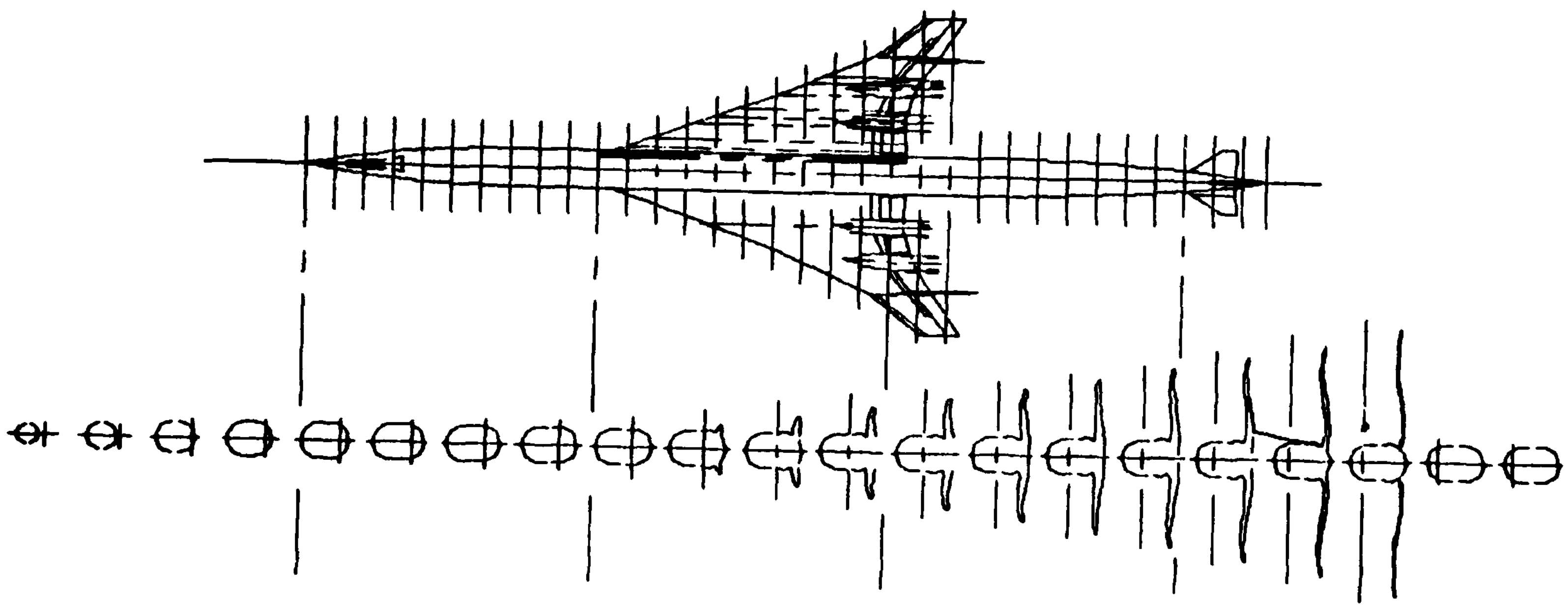
TYPE OF ANALYSIS DATA

- PARAMETRIC (SINGLE VALUE)
  - AREAS, LENGTHS, ETC.
- GRIDS
  - 3-D POINTS, LINE ELEMENTS, PANELS
- SURFACES
  - CURVES WITH SPATIAL RELATIONSHIPS, ETC.

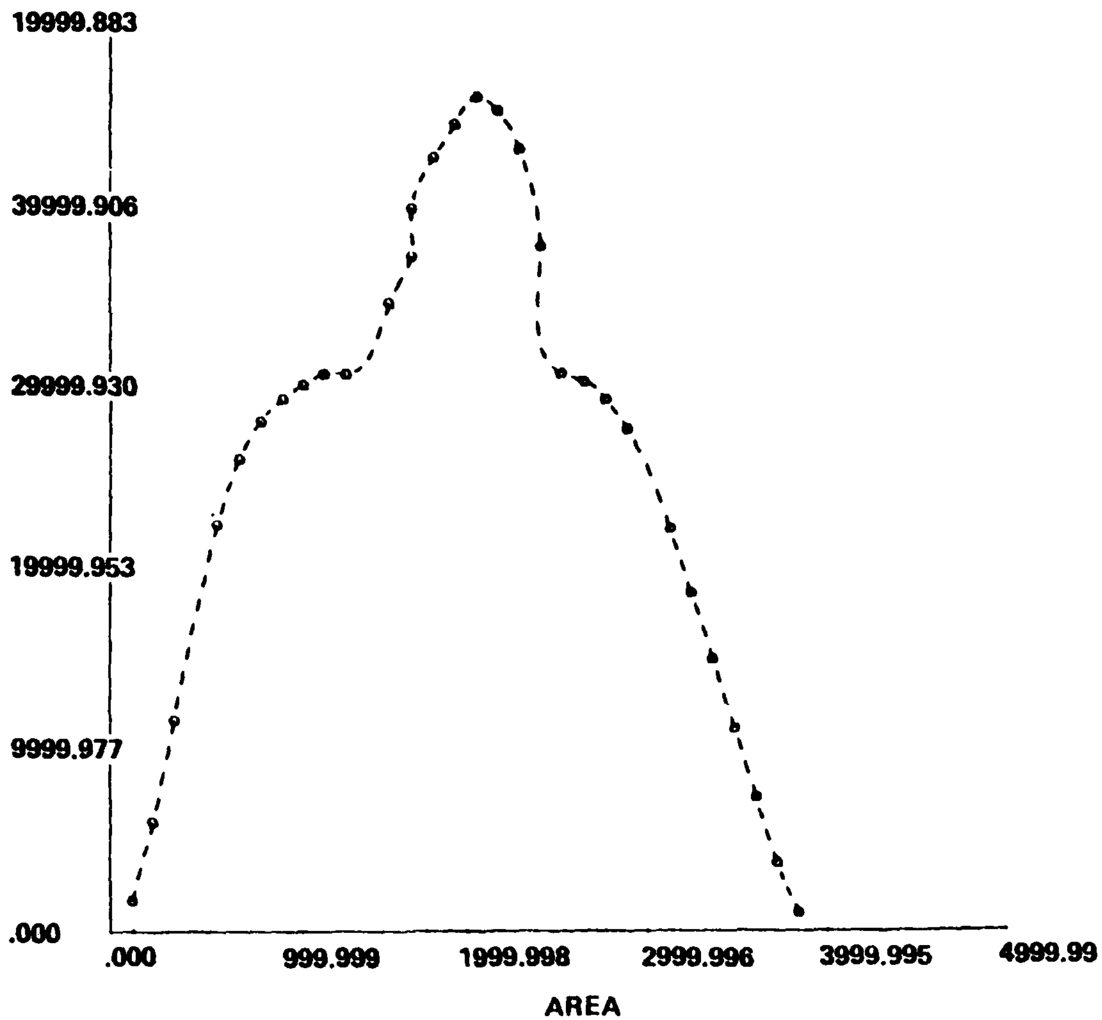
MISSION ANALYSIS



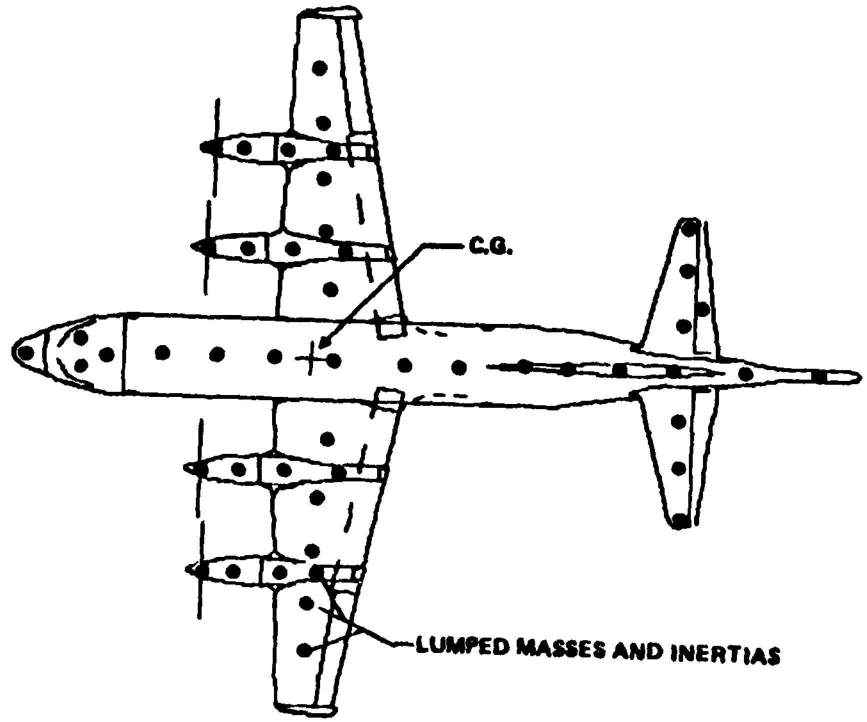
AREA PROGRESSION



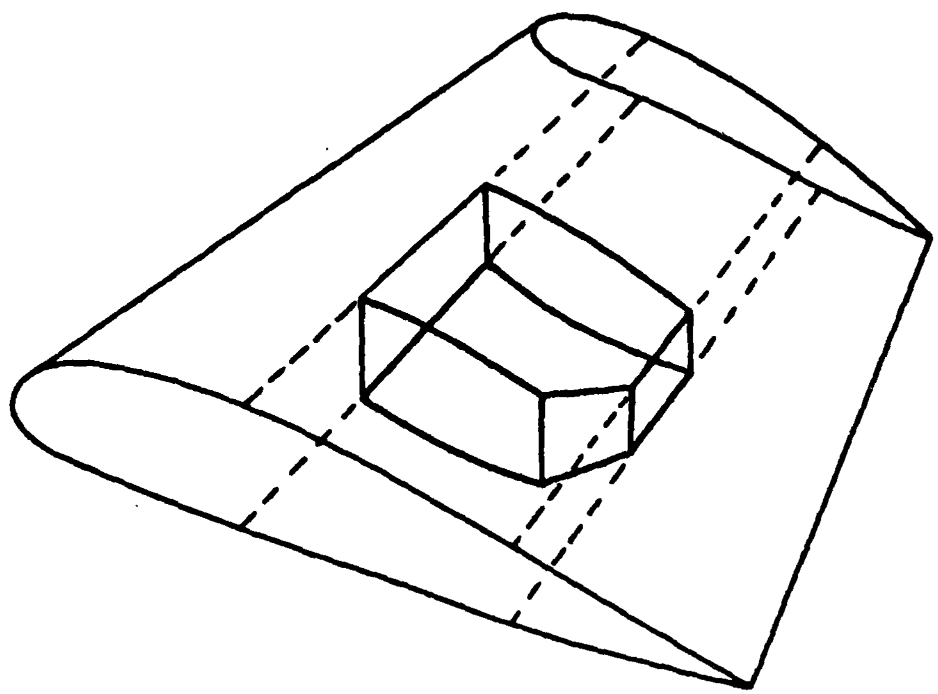
AREA PROGRESSION OUTPUT CURVE



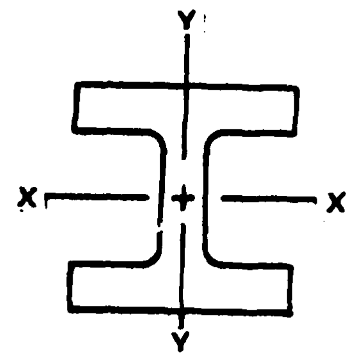
WEIGHT AND BALANCE



FUEL TANK STUDIES

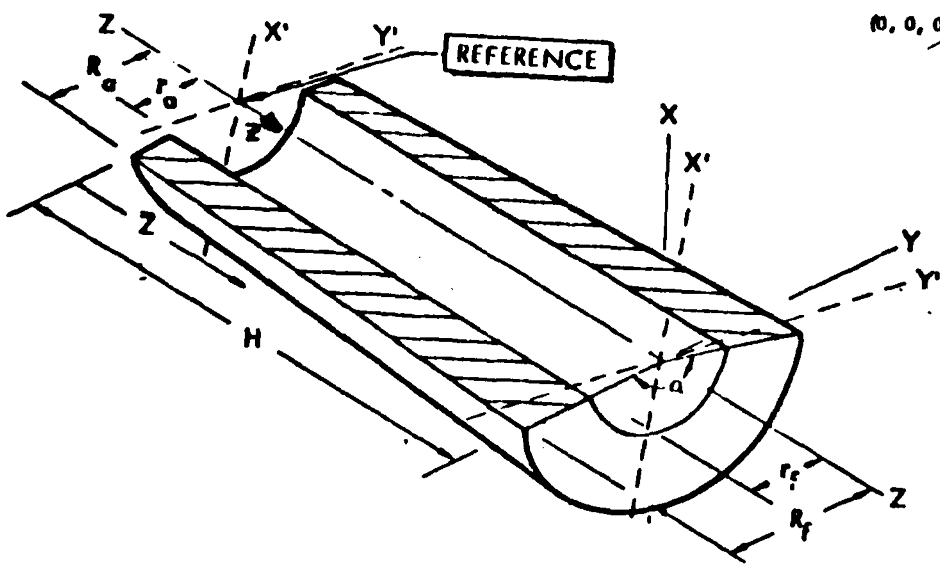


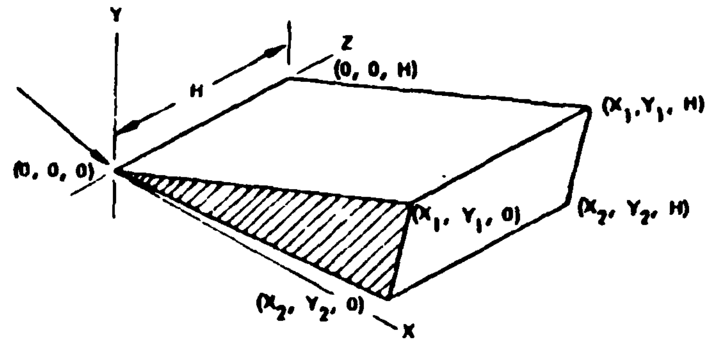
DETAIL MASS AND SECTION PROPERTIES



SECTION PROPERTIES

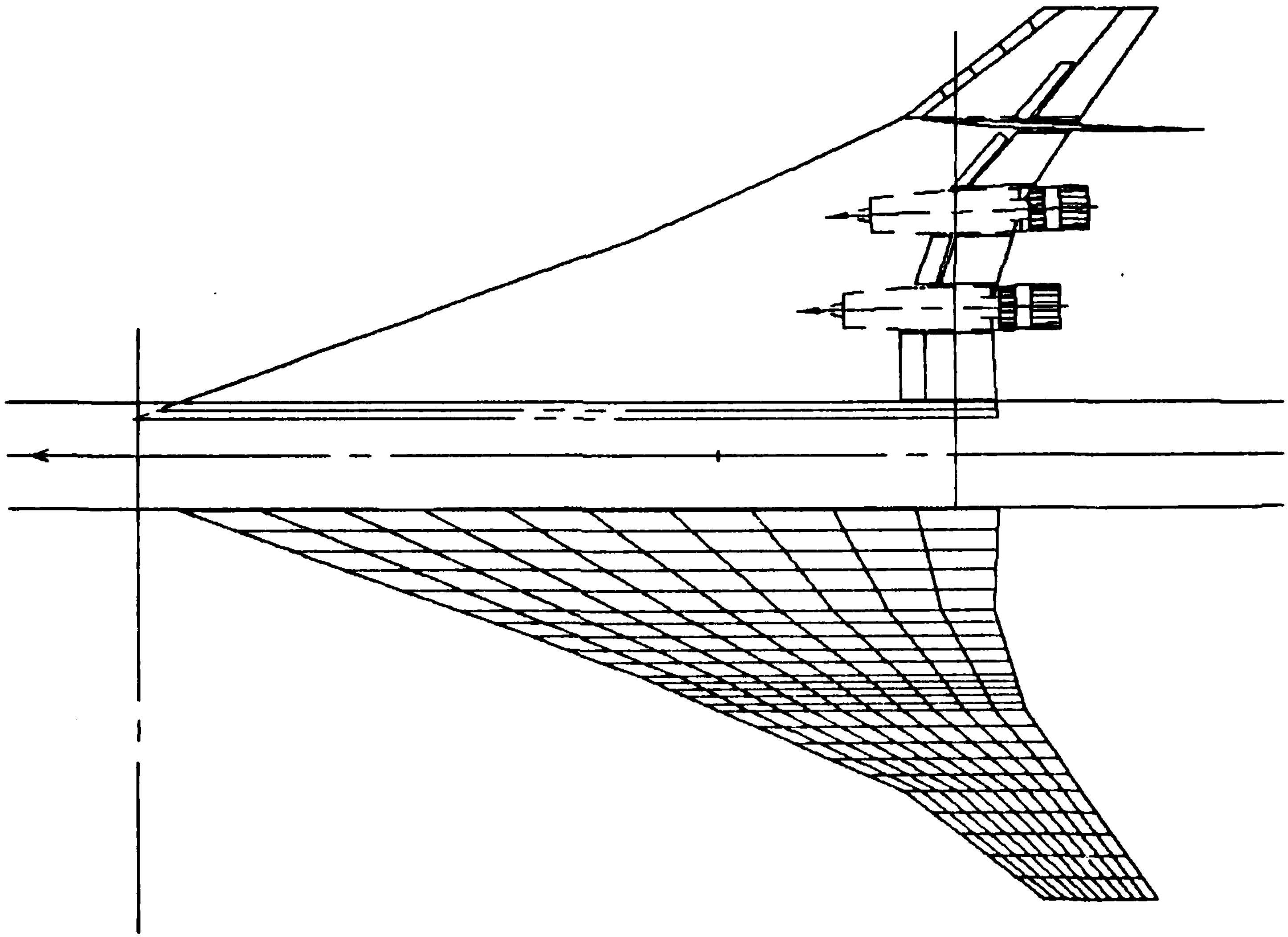
SURFACE OF REVOLUTION



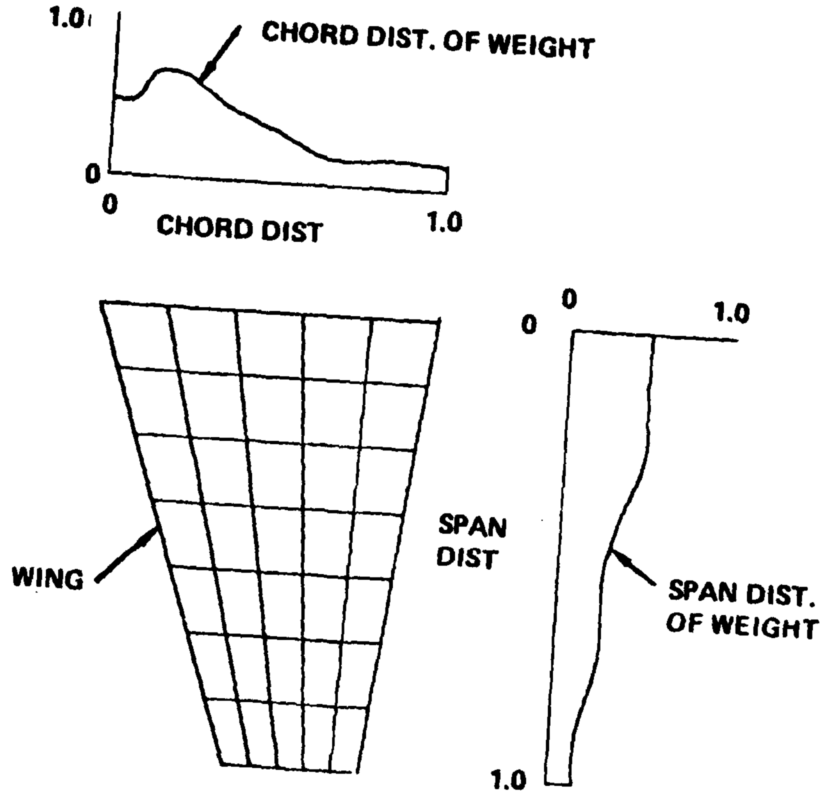


CONSTANT THICKNESS

VORTEX - LATTICE MODELING

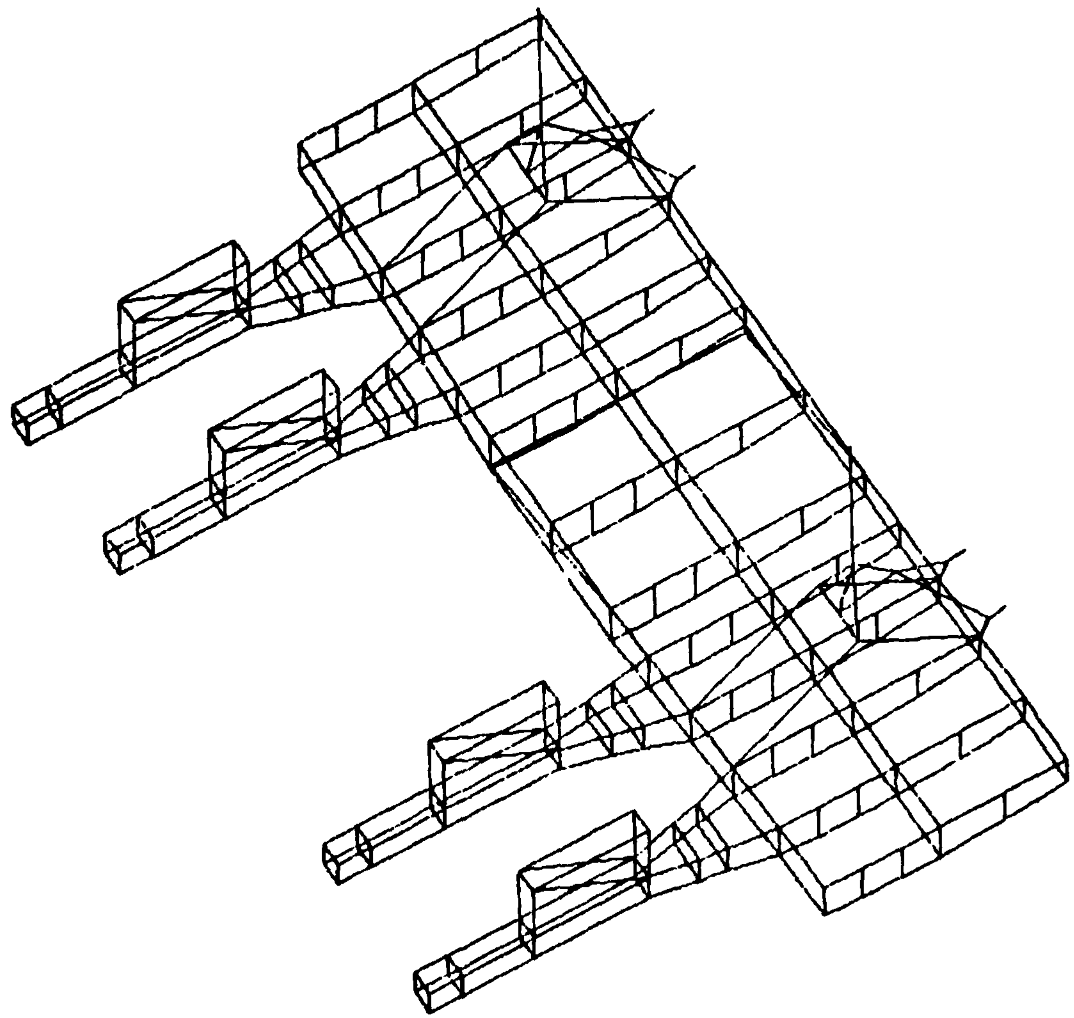


MASS DISTRIBUTION

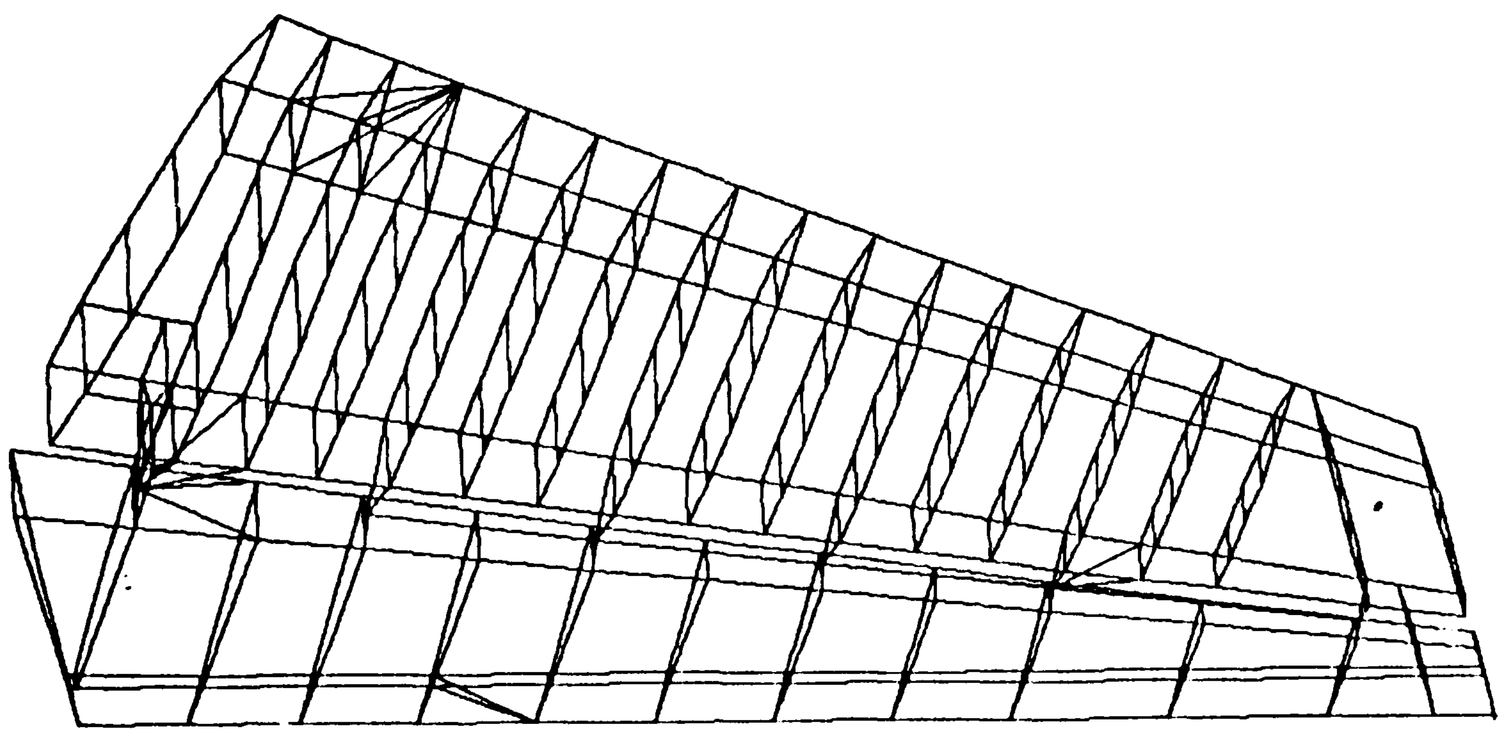


SUB-DIVIDED WING WITH WEIGHT CURVES

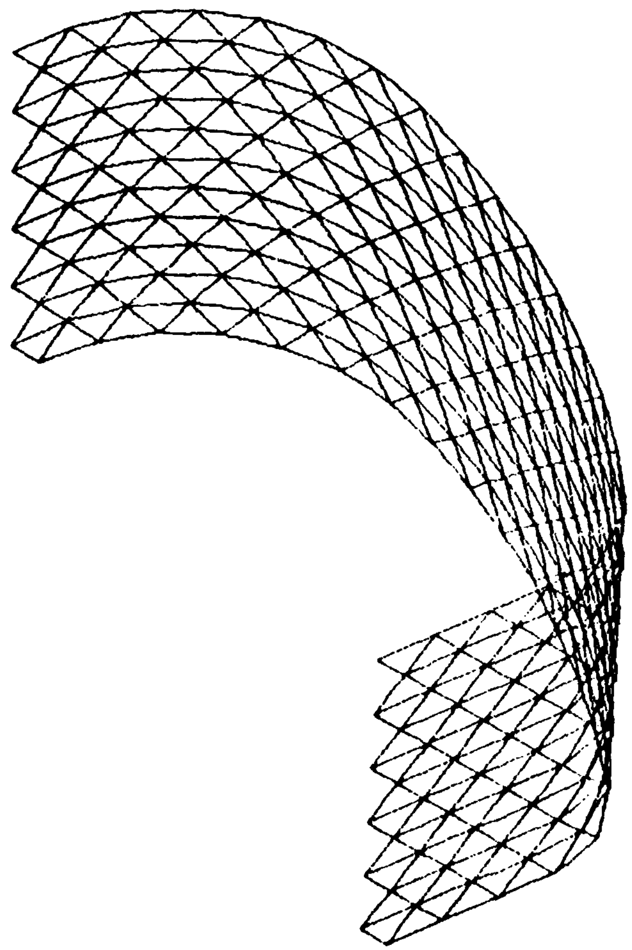
VSTOL WINGBOX



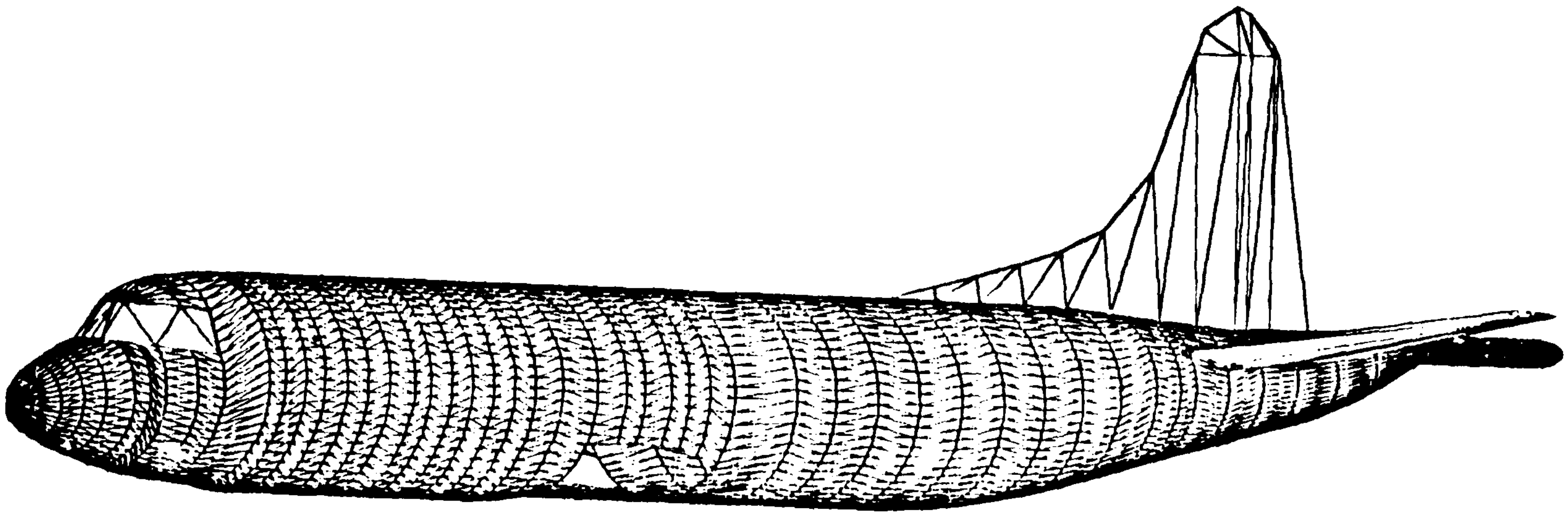
L-1011 VERTICAL FIN



COMPOSITE STRUCTURES



SURVIVABILITY MODELING



VIEW FROM 45 0

P-3C SURVIVABILITY STUDIES: AN APPLICATION OF COMPUTER-AIDED DESIGN

Donald E. Tuttle
and
Kimber L. Johnson
Lockheed-California Company
Burbank, California

P-3C SURVIVABILITY STUDIES: AN APPLICATION OF COMPUTER-AIDED DESIGN

Donald E. Tuttle
and
Kimber L. Johnson
Lockheed-California Company
Burbank, California

The P-3C is an antisubmarine warfare (ASW) aircraft with an expanding role in antisurface warfare (ASUW). This expanding role has increased concern over the survivability of the aircraft during encounters with surface combatants and with long-range fighter aircraft. Additionally, the capability exists for future arming of submarines with underwater launched anti-air missiles.

Lockheed is currently conducting studies for the Navy on the vulnerability of the P-3C. We are also studying improvements that can be used to increase the overall survivability of the aircraft and improve its effectiveness in the ASW and ASUW role.

Computer-aided design has been used in all aspects of the analysis. The accompanying viewgraphs indicate some of the areas studied.

Mission analysis and force requirements studies are based on analysis of encounters occurring during global warfare. ASW operations occur in three areas: along barriers that are used to monitor traffic through choke points such as exist between Great Britain and Greenland, along convoy routes, and in open sea areas where ballistic missile submarines operate. The world map indicates these operating areas and the potential for long-range Soviet aircraft operating in an armed role to act against the patrol aircraft. Additional threats exist when the aircraft is used in a surface search role where encounters with surface forces can subject the aircraft to surface-to-air missiles (SAM) and anti-air artillery (AAA).

The geometric model for assessing aircraft vulnerability was created using the Lockheed CADAM* system. Aircraft "drawings" were accessed and data points put in a temporary data set within CADAM. The data was then copied into a new data set and at the same time formatted for RAWGEN input thru a separate subroutine. Components within the aircraft were modeled using standard shapes such as cylinders or boxes.

* Registered trademark of the Lockheed Corporation

Survivability studies performed include the effects of susceptibility reduction through use of ESM, ECM, and IRCM. These studies have included analysis of the effects on the P-3C and on a new design alternative called the MPA. Also studied have been the effects of adding alternative lethal defense systems including the Phoenix, Sparrow or a conceptual small anti-missile missile. These studies have been carried out to ascertain the attrition levels and the expected life cycle costs of the various concepts with differing threat levels.

The broad range of studies carried out in this program are based on using computers as an aid in design. Computers at Lockheed provide the capability for broad-based comprehensive survivability studies. These studies are continuing in conjunction with Navy studies to define an Advanced P-3 aircraft that will be both effective and combat survivable.

UNCLASSIFIED

ADVANCED P-3

SURVIVABILITY/VULNERABILITY

UNCLASSIFIED

MAD 81 368 3

OBJECTIVES

- TO ASSESS THE CURRENT STATE OF THE P-3 SURVIVABILITY
- TO IDENTIFY LIKELY THREAT IMPROVEMENTS IN NEXT FIFTEEN YEARS
- TO IDENTIFY AND EVALUATE P-3 MODIFICATIONS AND TACTICS WHICH WILL MAINTAIN P-3 EFFECTIVENESS IN A HOSTILE ENVIRONMENT

PATROL AIRCRAFT S/V TRENDS
1915 – 1981

- PRE-WORLD WAR II: S/V OF RISING CONCERN
- WORLD WAR II: S/V PEAK
- POST-KOREAN WAR: S/V REGRESSION
- P-3 AIRCRAFT: 1955 "UNDEFENDED AREA" CONCEPT
- THREAT TRENDS OMINOUS

S/V IMPROVEMENT REQUIRED

MAD 81-512.4

S/V CHARACTERISTICS

CURRENT P-3 FLEET

- MET 1955 ''UNDEFENDED AREA'' LAND PLANE SCR
- S/V DESIGN - SECONDARY FUNCTION OF FLIGHT SAFETY
  - FAIL-SAFE STRUCTURE: +3.0g −1.0g
  - CONVENTIONAL FLIGHT CONTROL SYSTEM
  - WET WING - 4 INTEGRAL TANKS
  - PRESSURIZED FUSELAGE
  - NO ARMOR
  - NO DEFENSIVE ARMAMENT
  - ESM — SUBMARINE SIGNAL INTERCEPTION

CURRENT NAVY PLANS: RETAIN IN FLEET UNTIL ~ 2025

MAD 81 511 4

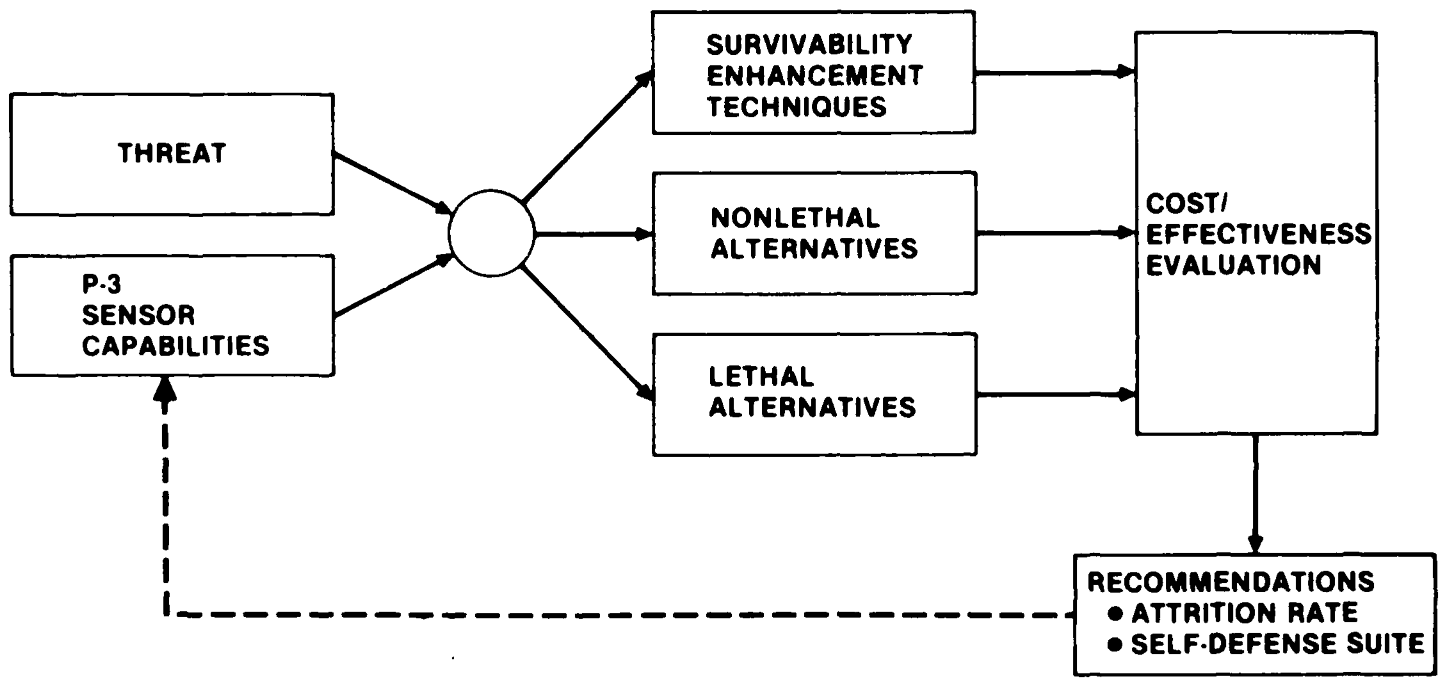
SURVIVABILITY GOALS

- MINIMAL COMPROMISE OF ESSENTIAL DESIGN CRITERIA
- COST EFFECTIVE TECHNIQUES IN TOTAL SYSTEM CONTEXT
- CAPABILITY TO PERMIT INDEPENDENT ACCOMPLISHMENT OF MISSIONS
- CAPABILITY TO RETURN TO BASE GIVEN DEFINED HIT

MAD 81 510-4

UNCLASSIFIED

SELF DEFENSE STUDIES



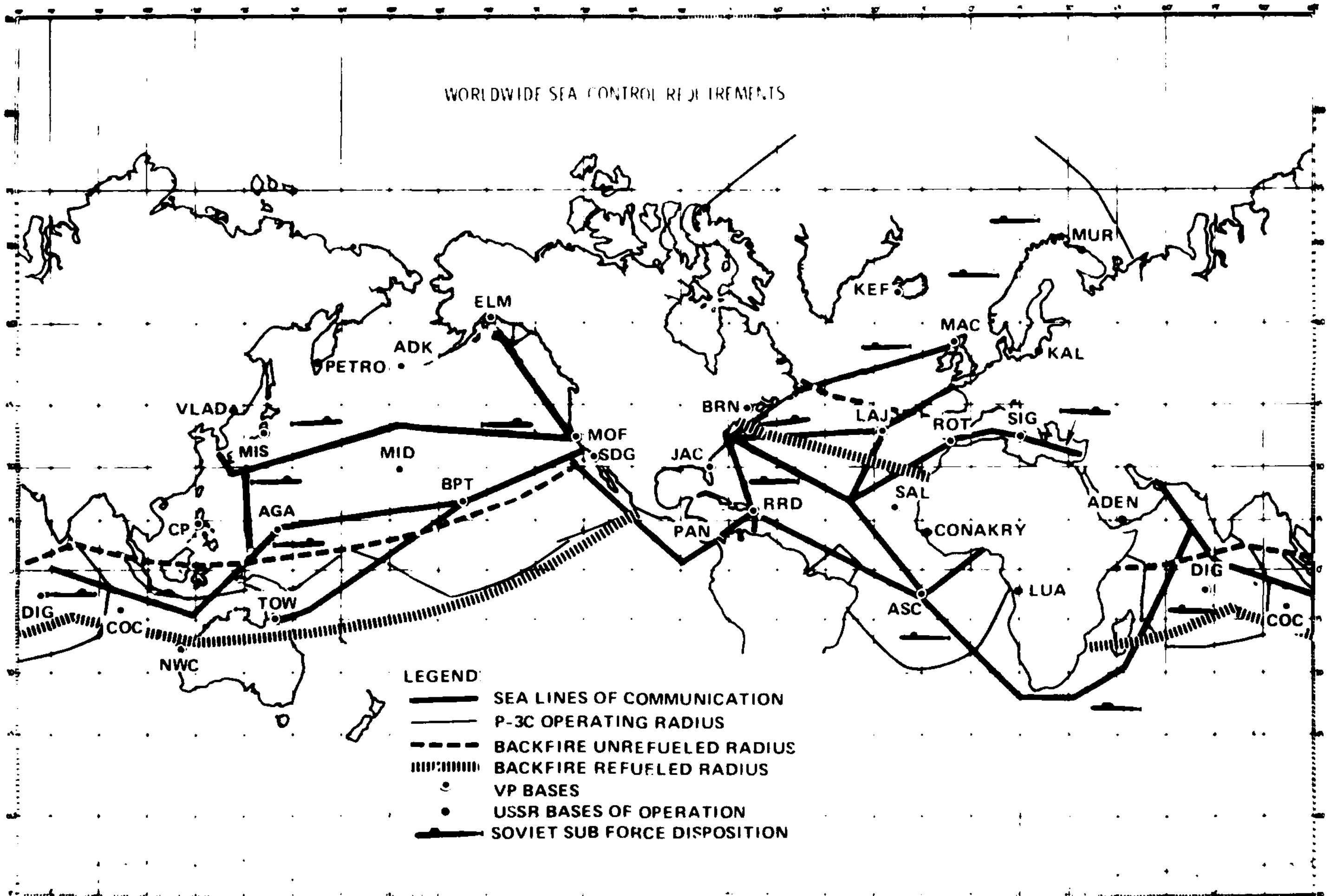
UNCLASSIFIED

MAD 79 1791 1

UNCLASSIFIED

WORLDWIDE SEA CONTROL REQUIREMENTS

PATROL AIRCRAFT PERSPECTIVE



UNCLASSIFIED

MAD 81-437

S/V THREAT MECHANISMS

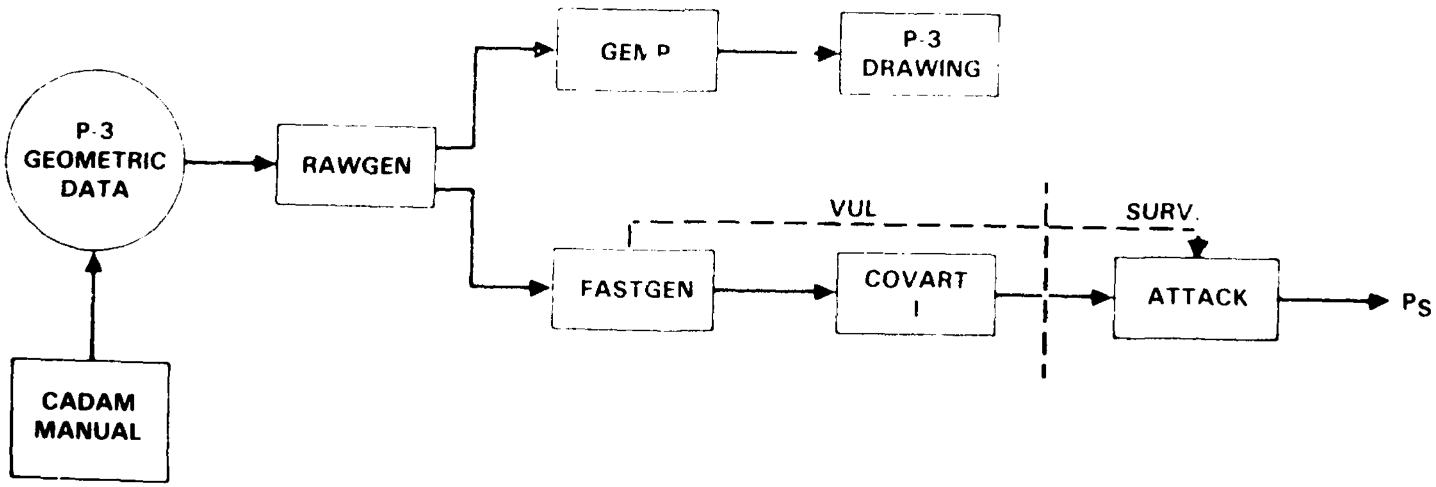
THREAT	HAZARD
GUNS	
AIR - AIR	BULLETS
SHIP AA	INCENDIARY
MISSILES - RADAR - IR	
AIR - AIR	FRAGMENTS
SHIP - AIR	BLAST
NUCLEAR	BLAST
	GUST
	THERMAL
	TREE
	EMP

MAD 81-514-4

UNCLASSIFIED

S/V METHODOLOGY

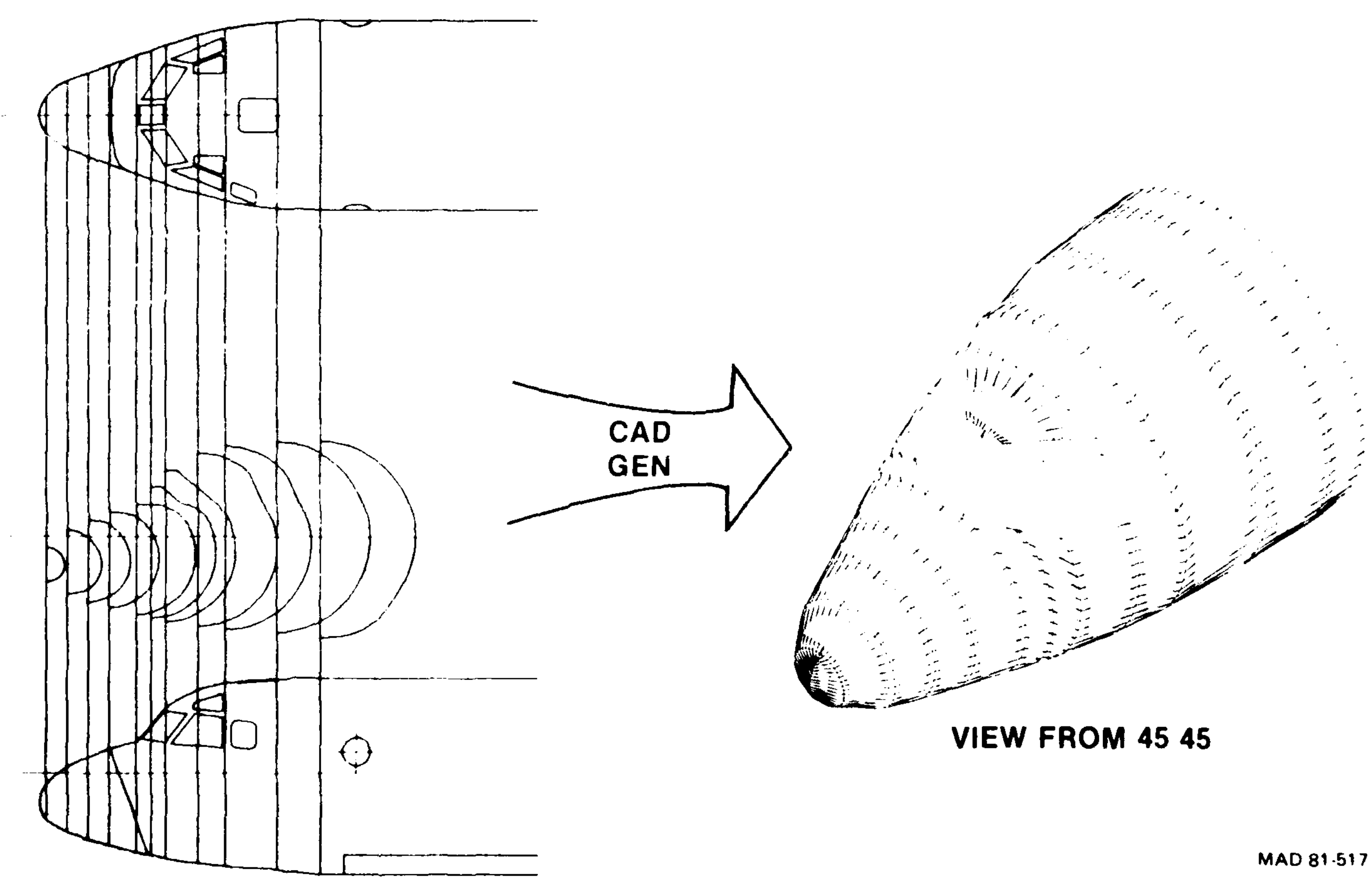
CADAM	"COMPUTER AUGMENTED DESIGN AND MANUFACTURING" CALAC COMPUTER GRAPHICS SYSTEM	RAWGEN	COMPUTER GEOMETRIC COORDINATE DATA FOR INPUT TO FASTGEN	COVART	COMPUTES VULNERABLE AREA (AV) BASED ON FASTGEN SHOTLINE ARRAYS AND PERTINENT THREAT DATA
GEMP	"GEOMETRIC MODEL PLOTTING" PROGRAM	FASTGEN	APPLIES SHOTLINES TO AIRCRAFT MODEL	ATTACK	COMPUT S SINGLE SHOT PROBABILITY OF KILL VERSUS CEP AND MISS DISTANCE



UNCLASSIFIED

MAD 81 193

CADAM TO RAWGEN

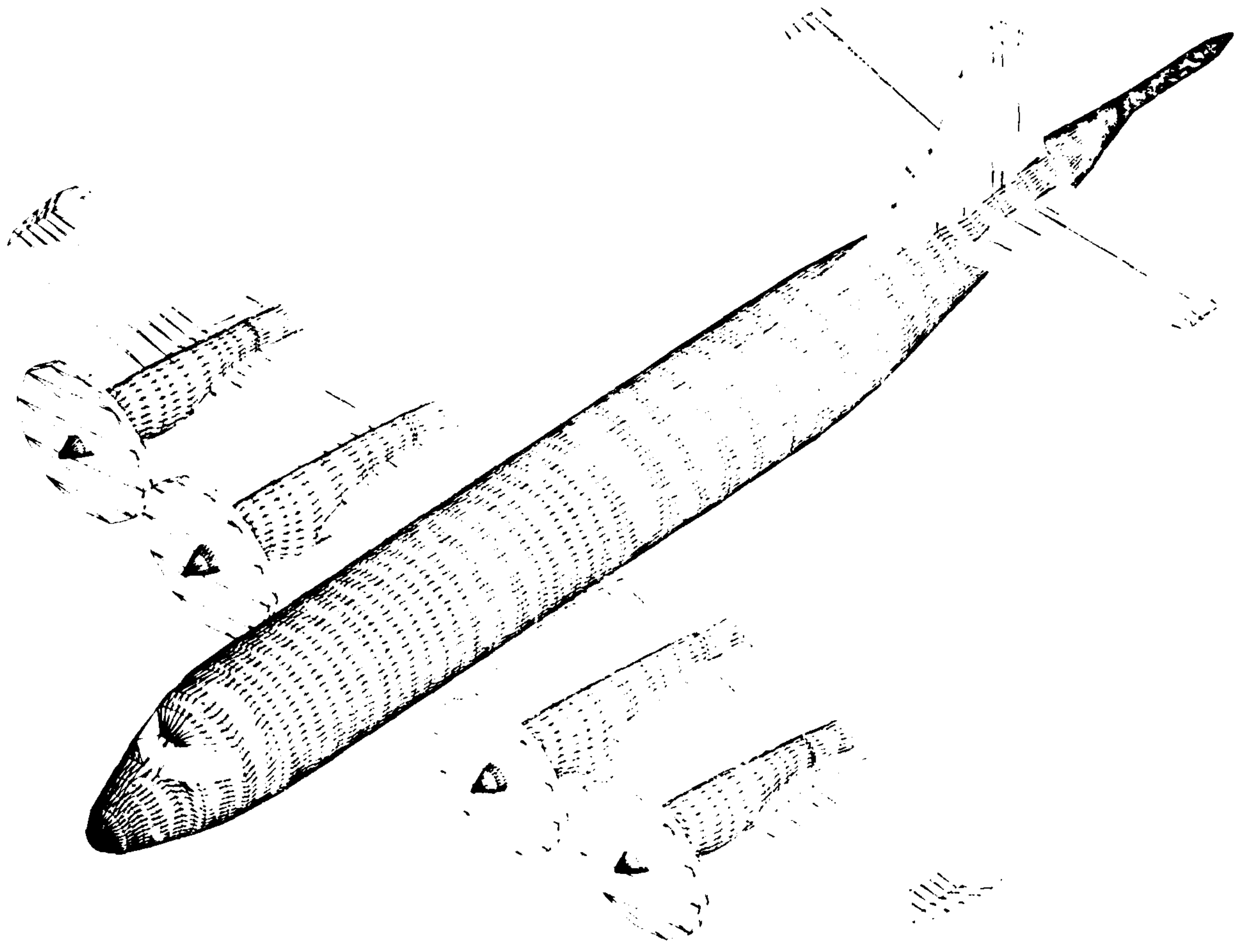


MAD 81-517 -4

UNCLASSIFIED

P-3 SURVIVABILITY

JTCG/AS — CADAM MODELING

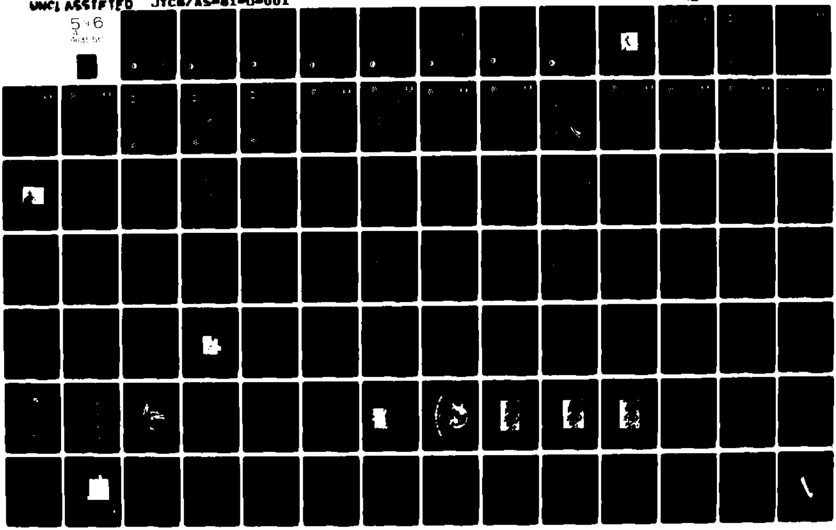


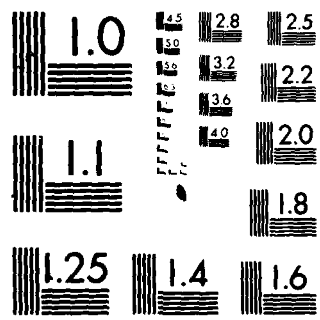
UNCLASSIFIED

MAD 81-509-4

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-D-001 NL

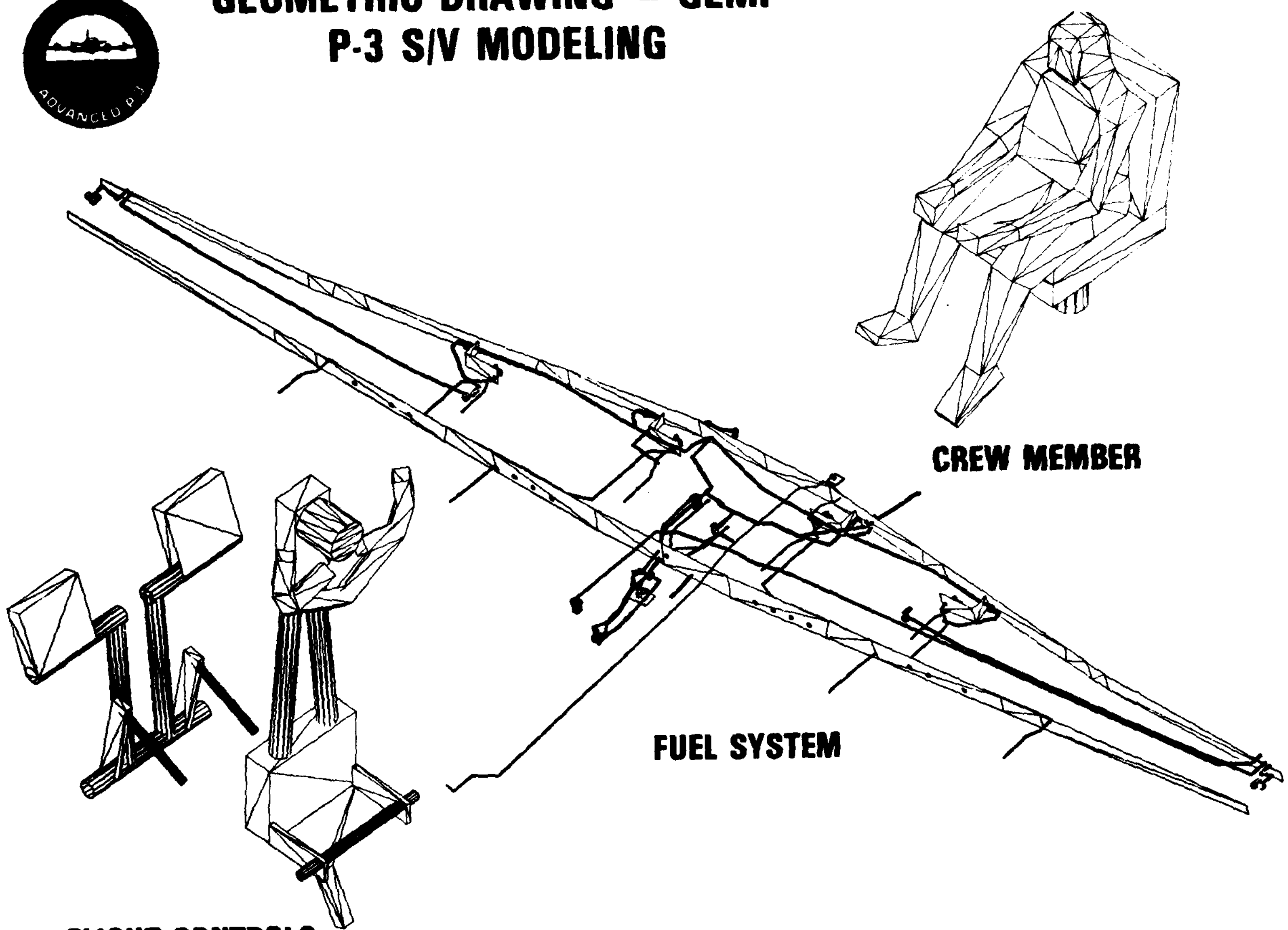
5 of 6





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

GEOMETRIC DRAWING — GEMP
P-3 S/V MODELING



MAD 81-361-3

P-3 S&V ASSESSMENTS

	VULNERABILITY	PROTECTION INHERENT IN P-3 DESIGN	POTENTIAL VR IMPROVEMENTS
FUEL SYSTEM			
TANKS	FIRE OR EXPLOSION	NONE	FOAM IN TANKS
DRY BAYS	FIRE OR EXPLOSION	NONE	FOAM IN BAYS
FUEL LINES	LEAKS & FIRES	FUEL LINES INSIDE TANKS TRANSFER & CROSS FEED	–
FLIGHT CONTROLS	LOW EXCEPT ELEVATORS COULD BE JAMMED IN POSITION	REDESIGN MECHANICAL CONTROLS	–
STRUCTURAL	AIRFRAME DESIGN VALIDATED BY TESTS FOR FAILSAFE CRITERIA	–	–
PROPULSION	NO PHYSICAL PROTECTION	FIRE EXTINGUISHERS 3 ENG MISSION CAPABLE 2 ENG RETURN FLT	–
AVIONICS	TO 3 KV/m EMP	DESIGNED & TESTED FOR LIGHTNING	SHIELDING DESIGN FOR EMP CRITERIA
CREW	NO DEDICATED PROTECTION	OTHER CREW MEMBERS CAN TAKEOVER	CONSIDER WIND-SHIELD PROTEC-TION, ETC.
ELECTRICAL	LOW	4 GENERATORS WORKAROUND DESIGN	DESIGN FOR EMP

MAD 81 191 1

UNCLASSIFIED

P-3 SELF DEFENSE OPTIONS

- ESM TO KEEP P-3 OUT OF SAM ENVELOPE AND ALLOW STANDOFF ATTACK OF SURFACE THREATS
- ESM & ECM TO PROVIDE WARNING AND FORCE ATTACKING AIRCRAFT INTO CLOSE RANGE WHERE AMRAAM OR SPARROW TYPE MISSILES CAN BE USED
- DEPENDENT ON SPW DEVELOPMENTS SMALL SHORT RANGE AMM's ARE BEING CONSIDERED

SPW — JOINT NAVY/AF SELF PROTECTION WEAPON PROJECT OFFICE AT EGLIN AFB

UNCLASSIFIED

MAD 81 516 -4

UNCLASSIFIED

P-3 RADAR/IR SUSCEPTABILITY

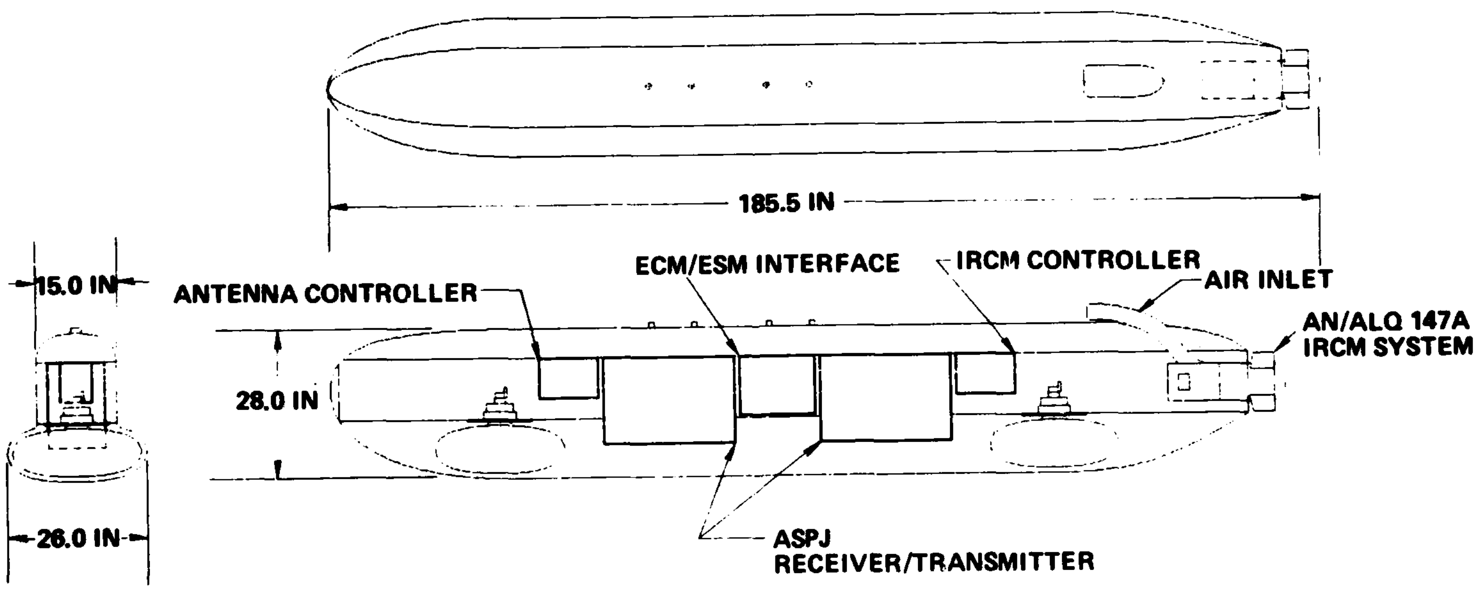
- TARGET SIZE (RADAR)
  - RELATIVELY LARGE RADAR CROSS SECTION
    - SMALLER THAN B-52/C-130
    - LARGER THAN FIGHTER
    - CAN AND WILL BE DETECTED AND TRACKED
    - VULNERABLE WITHOUT ECM
- IR SIGNATURE
  - INFRARED CROSS SECTION SIMILAR TO C-130
    - IR THREAT ENVELOPE SLIGHTLY DIFFERENT ORIENTATION
    - DEFINITELY POSSIBLE TO DETECT AND TRACK WITHIN MISSILE FIRING ENVELOPE
    - VULNERABLE WITHOUT IRCM

MAD 81-84-1-4

UNCLASSIFIED

UNCLASSIFIED

ECM/IRCM POD

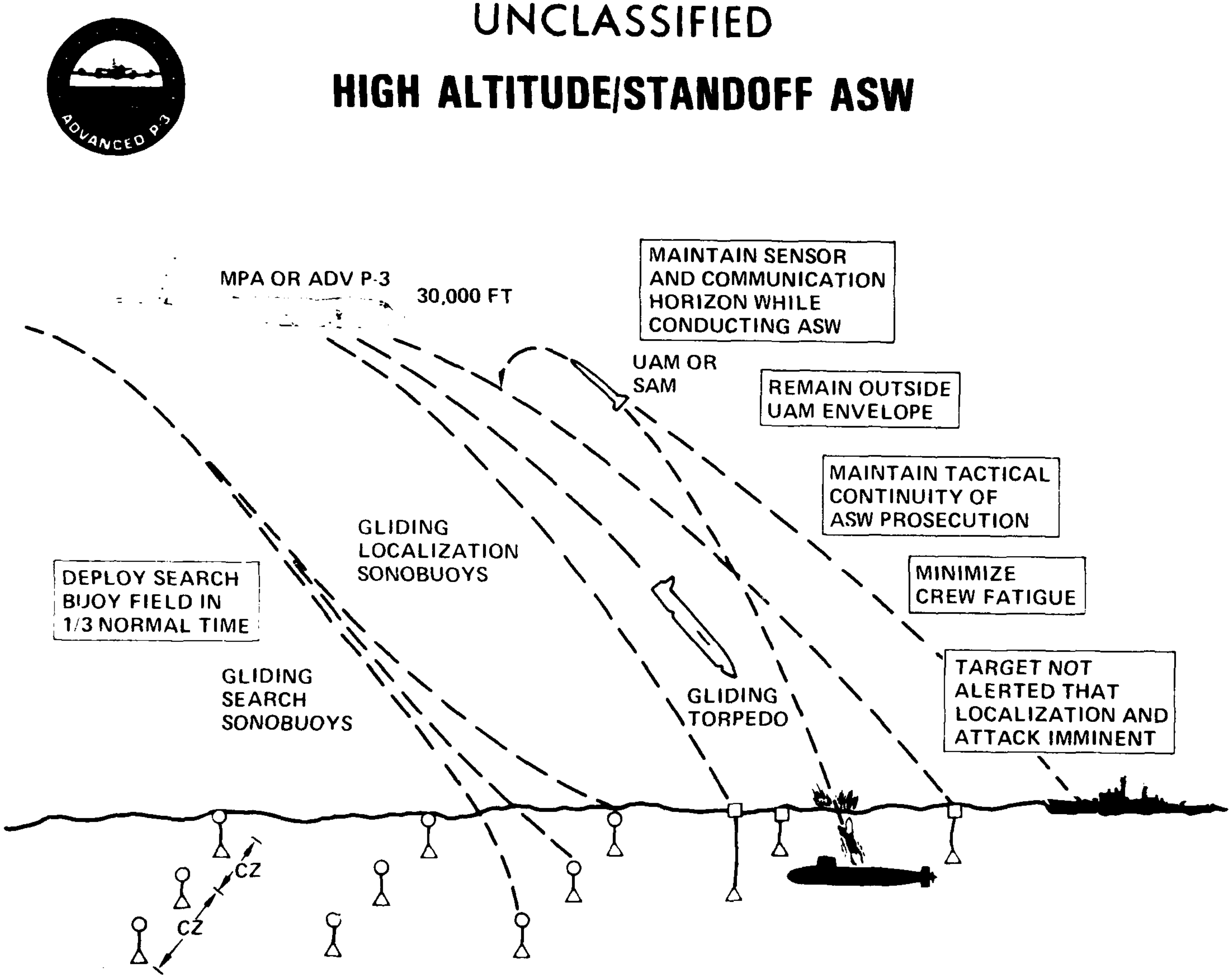


MAD 81-149-2

UNCLASSIFIED

UNCLASSIFIED

HIGH ALTITUDE/STANDOFF ASW



UNCLASSIFIED

UNCLASSIFIED

S/V ASSESSMENT

- **CONCERTED EFFORT TO EXAMINE KEY TRADEOFFS**
  - SURVIVABILITY ENHANCEMENT
  - NONLETHAL SELF-DEFENSE
  - LETHAL SELF-DEFENSE
- **TRADEOFF METHODOLOGY PERMITS QUANTITATIVE TRADE-OFFS**
  - COST OF SELF-DEFENSE AND SURVIVABILITY ENHANCEMENT SYSTEMS

    VS.

  - COST OF ATTRITION FOR EQUAL FORCE EFFECTIVENESS
- **ONGOING LOCKHEED INTERACTION IN THIS VITAL AREA WITH:**
  - NAVAIR (PMA-240), NWC CHINA LAKE, NSWC WHITE OAK, NPS MONTEREY, JTCG/AS, USAF
  - GD, GE, HUGHES, SANDERS

UNCLASSIFIED

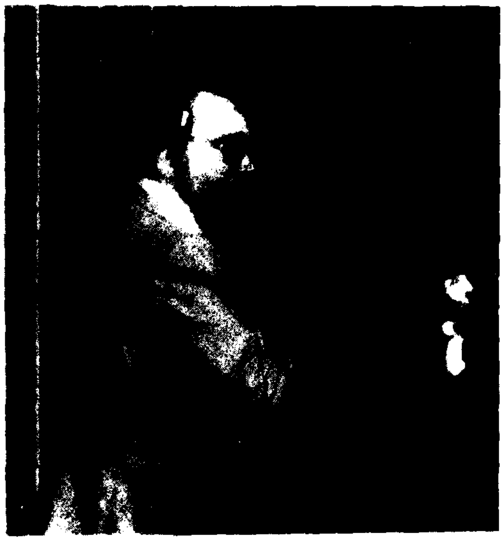
MAD 81 188 1

CONCLUSIONS

- THREAT TRENDS DRIVE ADVANCED P-3 S/V DESIGN
- SIGNIFICANT S/V IMPROVEMENT MANDATORY
- TRADE-OFFS COMPLEX
- COMPUTER AIDED DESIGN ESSENTIAL TO PROCESS

INTERACTIVE GRAPHICS FOR DISPLAY AND
MODIFICATION OF TARGET DESCRIPTIONS

Earl P. Weaver, Vulnerability/Lethality Division
Michael J. Muuss, Ballistic Modeling Division
ARRADCOM
Ballistic Research Laboratory
Aberdeen Proving Ground, Maryland



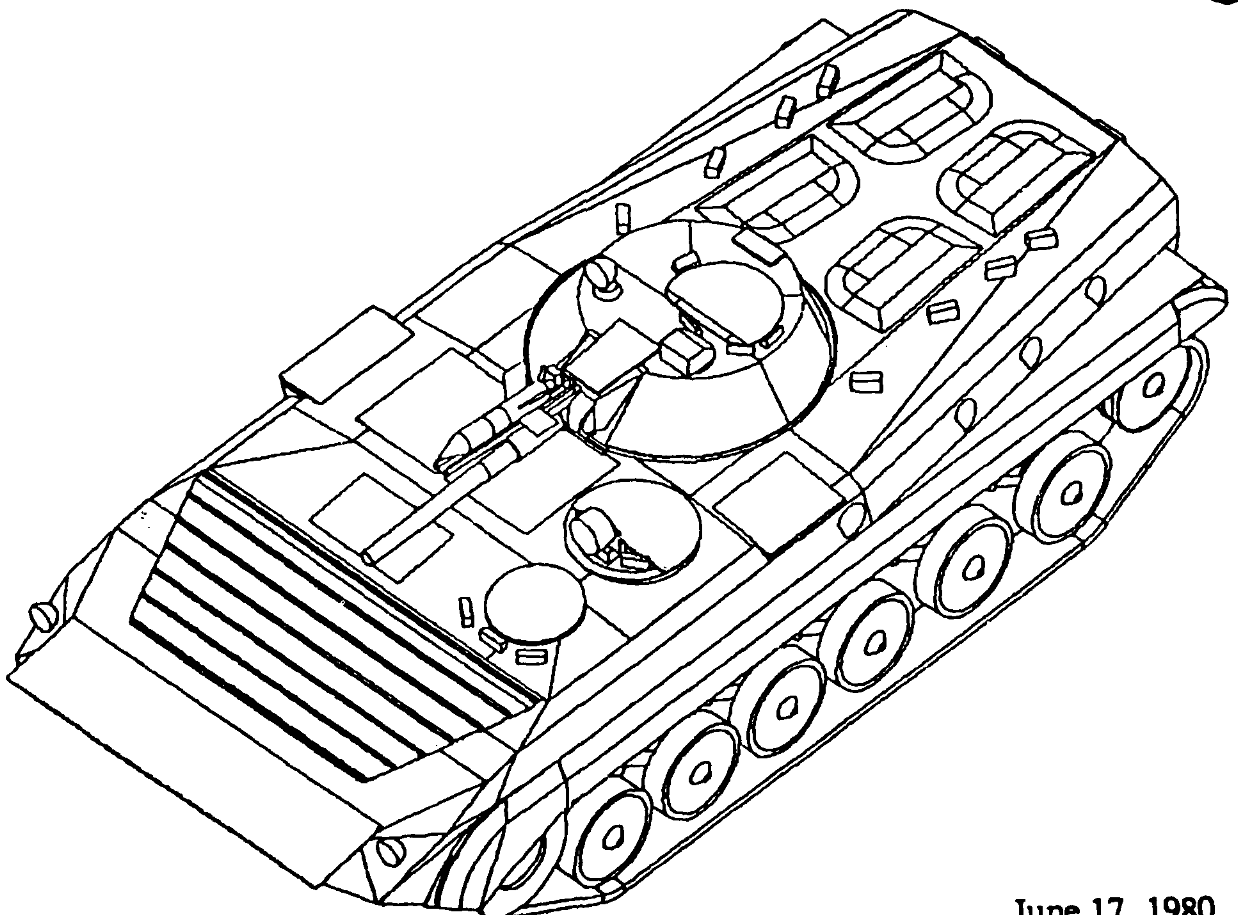
EARL P. WEAVER,
ARRADCOM

ARRADCOM
Ballistic Research Laboratory
Aberdeen Proving Ground
Maryland

INTERACTIVE GRAPHICS FOR DISPLAY AND MODIFICATION OF TARGET DESCRIPTIONS (U)

Earl P. Weaver — *Vulnerability/Lethality Division*
Michael J. Muuss — *Ballistic Modeling Division*

12 Nov 1980



June 17, 1980

TARGET MODELS PROVIDE:

- INPUT TO VULNERABILITY ASSESSMENT CODES
    - *Components/Compartments encountered*
    - *Angle of obliquity at point of impact*
    - *Component material*
    - *Component's line-of-sight thickness*
    - *Angle of exit*

- INFORMATION FOR ANALYSIS
    - *Weights*
    - *Volumes*
    - *Centers of gravity*
    - *Moments of inertia*
    - *Presented areas*
    - *Pictures*

June 17, 1980

BASIC FUNCTIONS OF A TARGET DESCRIPTION SYSTEM

- Represent the geometric/physical system under study by a model
- Create, delete, and change the model
- Display a representation of the model
- Analyze the model and output calculations based on it

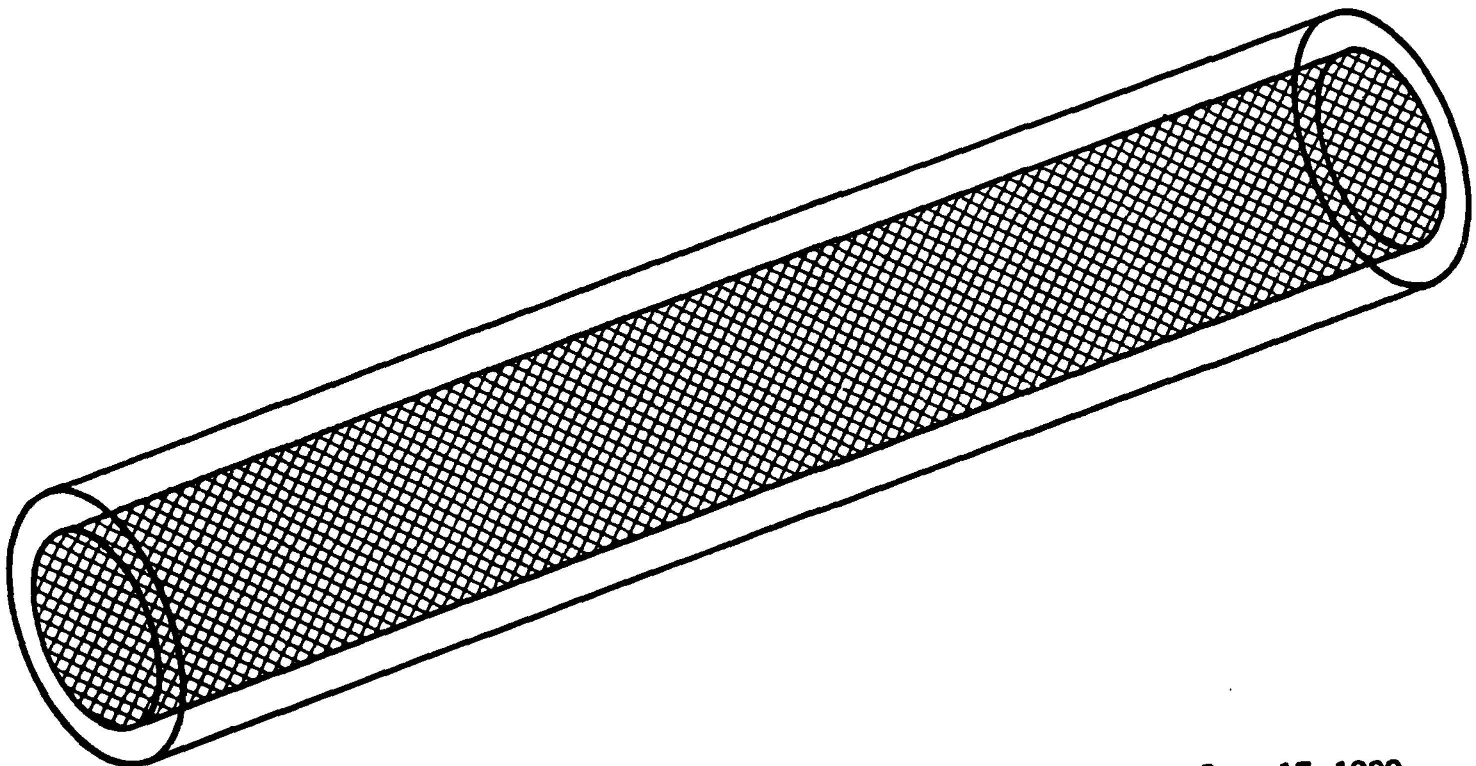
April 30, 1980

COM-GEOM

COMBINATORIAL GEOMETRY

- LIBRARY OF SHAPES
  - *Boxes*
  - *Cylinders*
  - *Spheres*
  - *Cones*
  - *Pyramids*
  - *Wedges*
  - *N-Faced Arbitrary Polyhedra*
  - *Others*
- COMBINE SHAPES USING
  - *Intersection*
  - *Subtraction*
  - *Union (OR)*

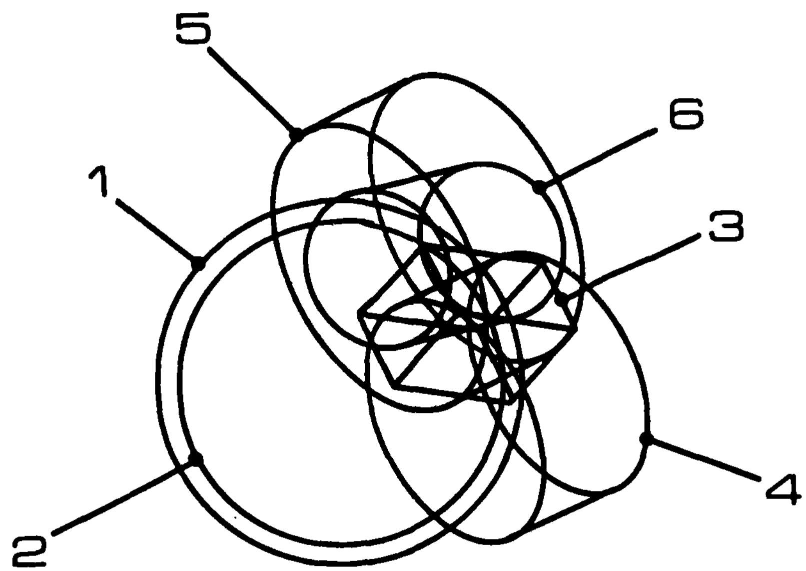
June 17, 1980



June 17, 1980

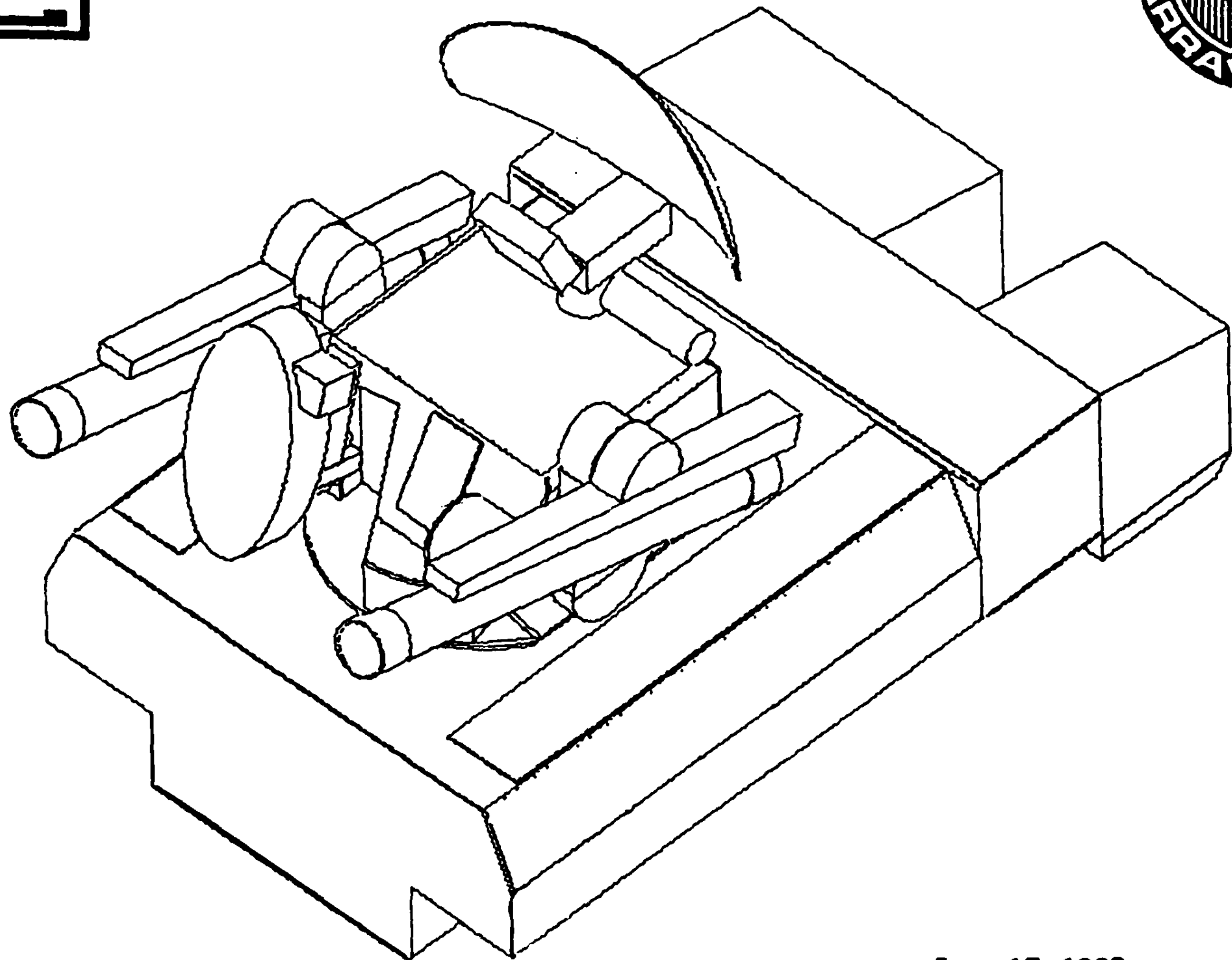
BRL

U.S. ARMY ARRADCOM



$1 - 2 \cap 3 \cap 4 \cap 5 \cap 6$

June 17, 1980



June 17, 1980

GENERATING A TARGET DESCRIPTION

- Determine "level of detail"
- Decide on construction of component
- Prepare data
- Validate model
  - *Check for overlap*
  - *Pictures*
  - *Shotlines*

April 30, 1980

PROBLEM AREAS

- Data Preparation
- Validation
- Modification

June 17, 1980

DESIGN OBJECTIVES

- **Real-time** functions
  - √ construction
  - √ viewing
  - √ modification
- Little or no explicit numerical input
- "Stock room parts bin" to eliminate redundant design work
- Interface to GIFT code

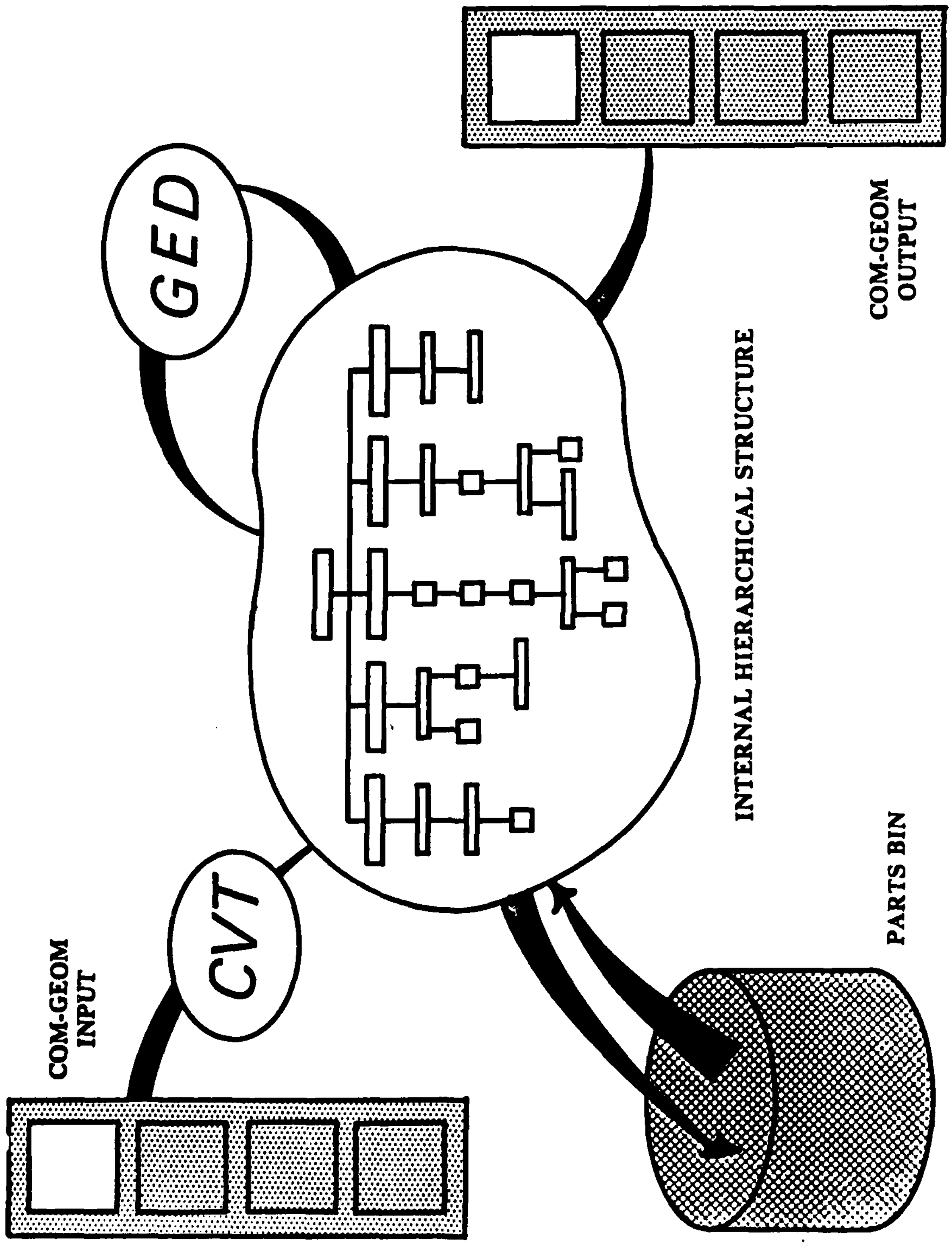
April 30, 1980

IMPLEMENTATION

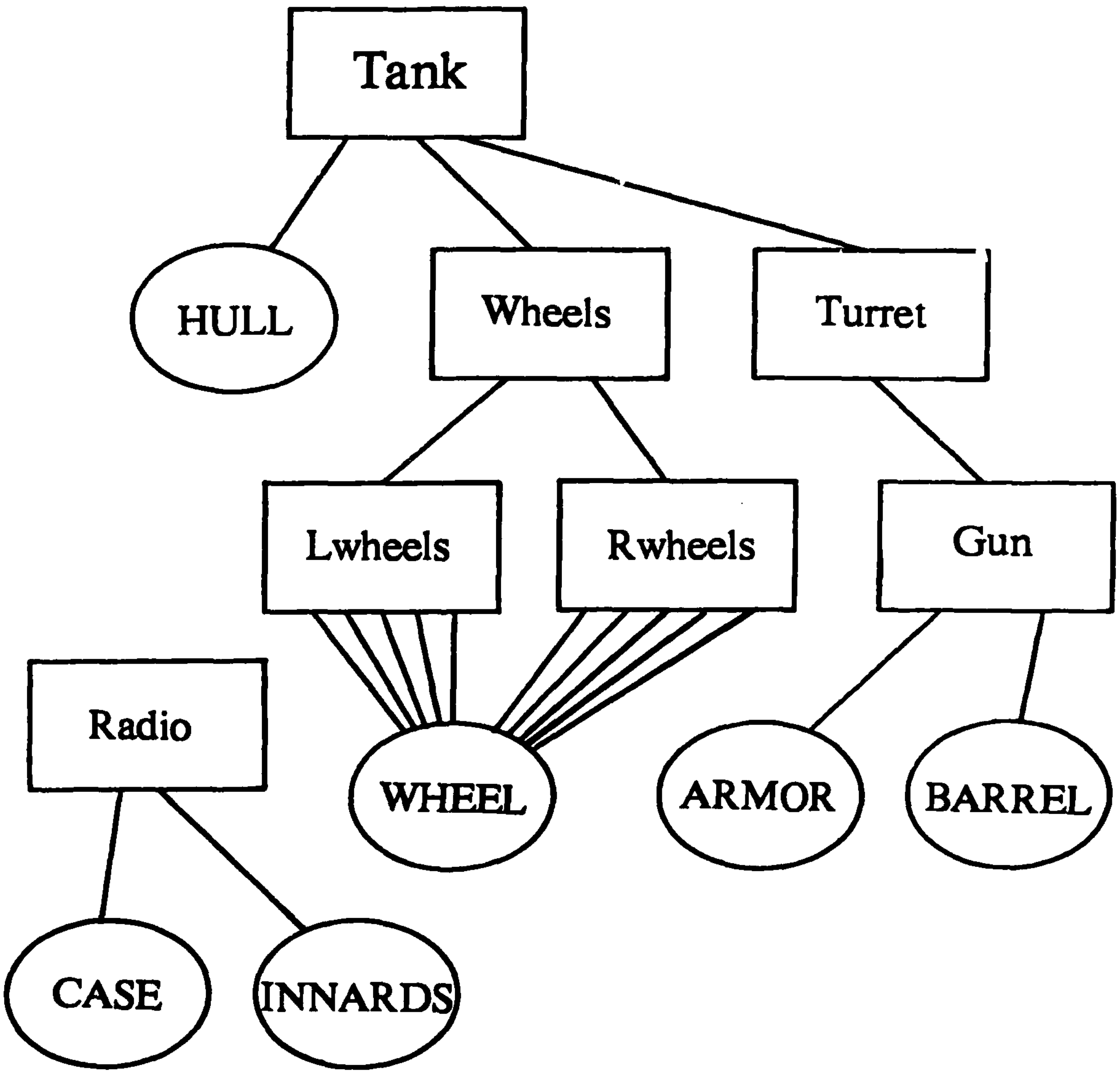
- GENERALIZED COM-GEOM SOLIDS
  - *Arbitrary 8-vertex polyhedron*
  - *Truncated general cone*
  - *Ellipsoid of revolution*

- DISPLAY LIMITATIONS
  - *Draw only solids (Dashed lines indicate subtracted solids)*
  - *No hidden line/surface removal*
  - *No complex edge generation*
  - *No perspective view (Depth cueing by decreased intensity)*

June 17, 1980


GED
COM-GEOM OUTPUT
INTERNAL HIERARCHICAL STRUCTURE
CVT
COM-GEOM INPUT
PARTS BIN

HIERARCHICAL OBJECT STRUCTURE



June 17, 1980

GED Features

- DISPLAY
  - *Show/erase parts*
  - *Pan*
  - *Arbitrary viewpoint*
  - *Zoom*
  - *Preset views*
  - *Slicing plane*
  - *Save viewpoint*
- MANIPULATION
  - *Create and delete assemblies*†
  - *Rename assemblies*
  - *Copy solids*
  - *"Instance" assemblies*
  - *Move assemblies*
  - *Scale assemblies*
  - *Modify solids*

† *Assemblies = Solids or Combinations*

June 17, 1980

IMPLEMENTATION DETAILS

- The C structured programming language
- The BRLNET-JHU/UNIX † operating system
- Vector General refresh display
  - *32 K byte display memory*
- DEC PDP-11/34 computer
  - *96 K words MOS*
  - *80 Megabyte disk*

† UNIX is a trademark of Bell Labs

June 17, 1980

BENEFITS OF GRAPHICS EDITOR

- Cheaper, faster, more useful target models
- Ability to modify model in real-time
- "Stock room parts bin" eliminates duplication of effort
- Increased productivity of Target Modeling Specialists
- Vulnerability reduction studies practical
- Ability to quickly implement engineering changes

June 17, 1980

TO ACCESS SURVIVABILITY AND COMBAT DAMAGE
IN AIRCRAFT DESIGN SELECTION

Paul T. Chan
Vought Corporation
Dallas, Texas

TO ACCESS SURVIVABILITY AND COMBAT DAMAGE IN AIRCRAFT DESIGN SELECTION

Paul T. Chan
Vought Corporation
Dallas, Texas

Vought's Aircraft Synthesis Analysis Program (ASAP) is a computerized synthesis model for conducting conceptual aircraft design and performance studies which include sizing, costing and optimization. To provide ASAP with effectiveness measures for use in parametric design tradeoffs (as inputs to the Optimization Module), Vought's Campaign Force Effectiveness Model (CFEM) was integrated into ASAP.

CFEM calculates the sortie rate capability of aircraft point designs, as influenced by mission time, aircraft attrition and down-time due to combat damage repairs and non-scheduled maintenance.

Input parameters include:

- Probability of aircraft loss inflicted by the defense
- Probability of aircraft damage inflicted by the defense
- Combat damage repair down-times and their distribution frequencies
- Non-scheduled maintenance down-times and their distribution frequencies.

CFEM also calculates force effectiveness based on:

- Payload radius
- Number of passes per sortie
- Number of sorites per day
- Expected number of targets killed per pass
- Initial force size
- Number of campaign days
- Weather conditions.

Outputs include a cumulative accounting of sorties generated, targets killed, aircraft losses, and ordnance delivered. The normalized effectiveness measure (in reference to equal force size or equal program cost) is passed over to ASAP's Optimization Module as a basis for parametric aircraft design tradeoffs.

The ASAP/CFEM methodology has been applied to the USAF Advanced Tactical Fighter Program. The ability of the combined methodology to handle a wide range of conceptual designs, and to establish successful point design selections, demonstrates the ASAP/CFEM's flexibility and usefulness. It is a valuable analytical tool for the computer-aided design technology.

This presentation is limited to a discussion of the CFEM model and its generation of force effectiveness as the objective function for the combined ASAP/CFEM integrated model.

To Assess Survivability and Combat Damage in Aircraft Design Selection

VOUGHT CORPORATION
an LTV company dallas

P1-1157-1

VOUGHT

Objective

To Describe the Application of Vought's ASAP/CFEM Methodology to Computer-Aided Aircraft Design. Particular Areas of Interest Pertain to:

- Use of Campaign Force Effectiveness Factor as Measure for Aircraft Design Optimization
- CFEMs Ability to Evaluate the Campaign Force Effectiveness of Point Design Aircraft
- Sensitivity of Campaign Force Effectiveness To Force Attrition

ASAP/CFEM Methodology

- ASAP is an aircraft synthesis program, which integrates various engineering disciplines and their interactions into effective aircraft designs. It not only can "size" an aircraft based on operational and mission requirements, but can also search for the "best" configuration in reference to the Merit Function.

VOUGHT

ASAP/CFEM Methodology

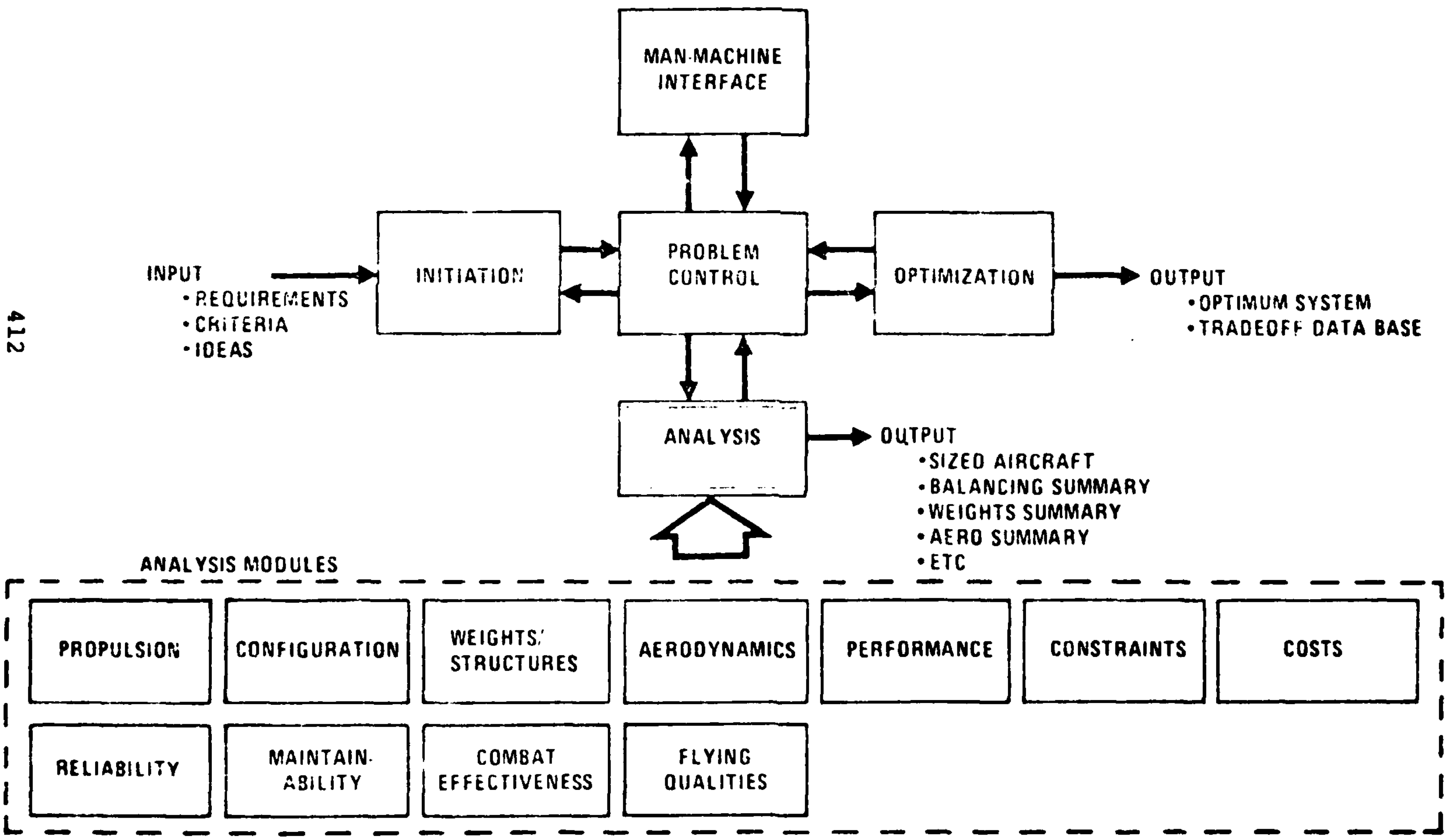
- CFEM Is a Bookkeeping Model.
  It Evaluates the Campaign Force Effectiveness of Combat Aircraft — Based on the Aircraft's:
  - Sortie Generation Capability
  - Target Kill Effectiveness

The Sortie Generation Parameter Is Sensitive to:

- Aircraft Survivability
- Combat Damage
- Unscheduled Maintenance
- Reliability
- Repair Downtime

VOUGHT

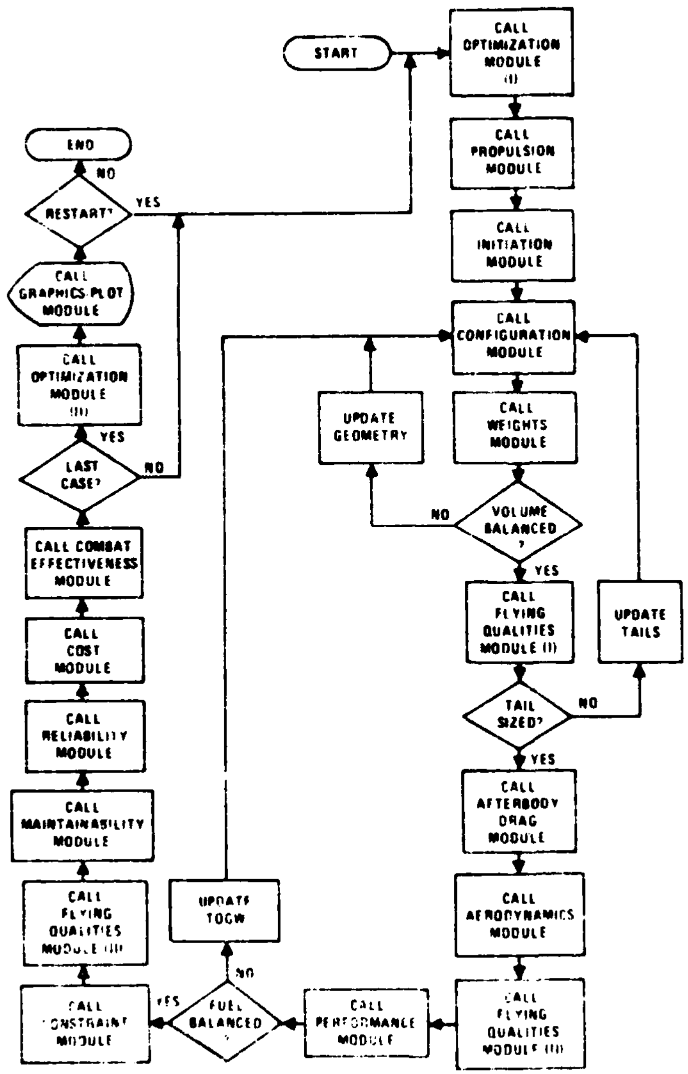
AIRCRAFT SYNTHESIS ANALYSIS PROGRAM (ASAP)



P4-424-11

VOUGHT

ASAP Logic Flow Diagram



INITIATION MODULE
- IDENTIFY NOMINAL AIRCRAFT CHARACTERISTICS
- DERIVE LAYOUT VIA ICG
- SPECIFY DESIGN SPACE

OPTIMIZATION MODULE
- (I) SELECT RESPONSE POINTS
- (II) ACTIVATES SEARCH PROCEDURE(S)

PROPULSION MODULE
- COMPUTE THRUST, FUEL FLOW AS f(ALT, M_N, P_S)

CONFIGURATION MODULE
- COMPUTE AIRCRAFT GEOMETRY

WEIGHTS MODULE
- COMPUTE FUEL AVAILABLE AT A GIVEN TOGW

FLYING QUALITIES MODULE
- (I) COMPUTE AERO DATA
- COMPUTE AEROELASTIC EFFECTS
- SIZE AND LOCATE SURFACE
- (II) TRIM AERO DATA
- (III) COMPUTE FLYING QUALITIES OPERATIONAL CONSTRAINTS

AFTERBODY DRAG
- COMPUTE THROTTLE DEPENDENT DRAG

AERODYNAMICS MODULE
- COMPUTE CRUISE CONFIGURATION LIFT AND DRAG

PERFORMANCE MODULE
- COMPUTE FUEL REQUIRED AT A GIVEN TOGW

CONSTRAINT MODULE
- COMPUTE PERFORMANCE OPERATIONAL CONSTRAINTS

MAINTAINABILITY MODULE
- COMPUTE AIRCRAFT AVAILABILITY, MAINTENANCE MAN HOURS PER FLIGHT HOUR

RELIABILITY MODULE
- COMPUTE PROBABILITY OF FAILURE, MISSION ABORT GIVEN FAILURE AND AIRCRAFT LOSS GIVEN FAILURE

COST MODULE
- COMPUTE AIRCRAFT COST

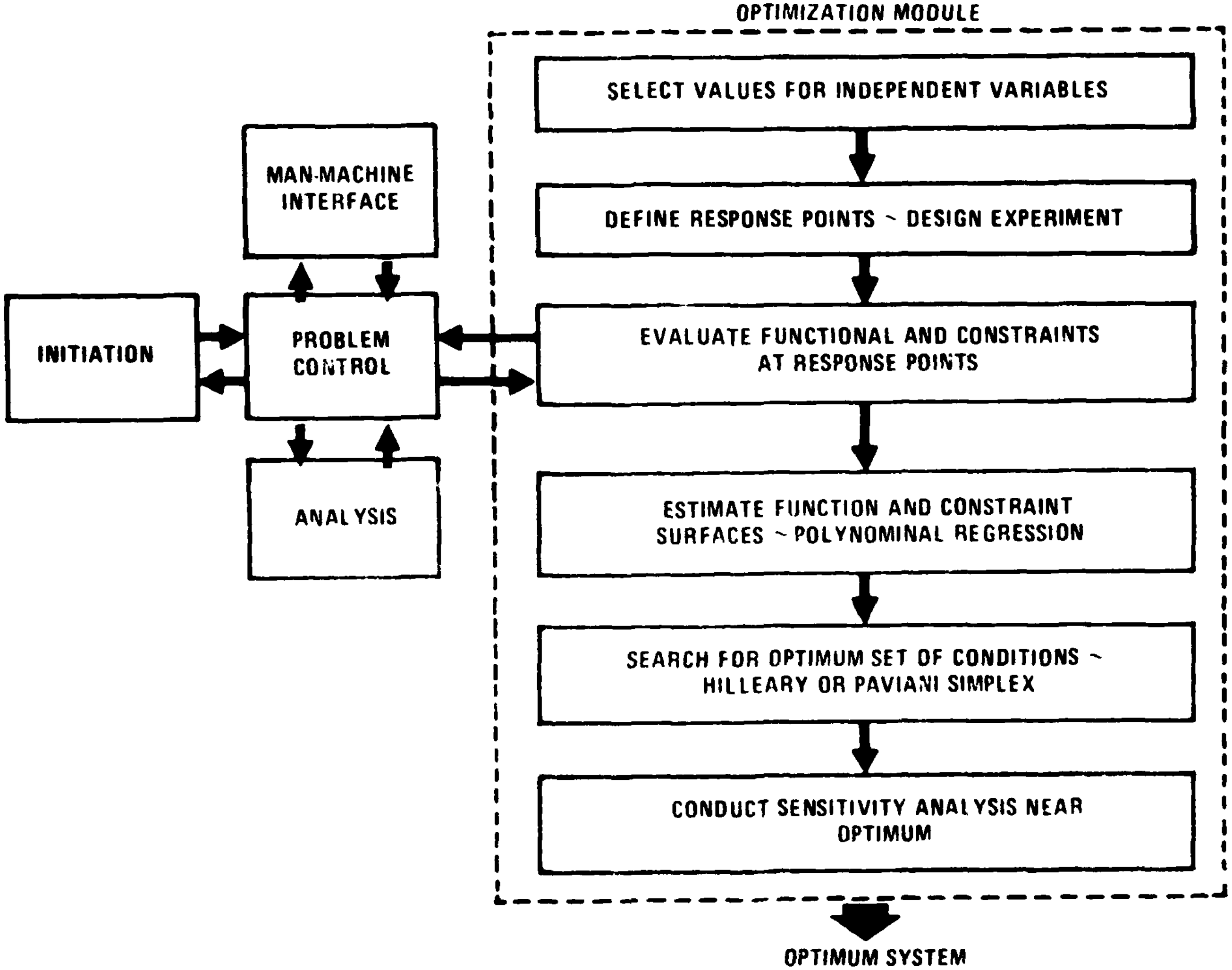
COMBAT EFFECTIVENESS MODULE
- COMPUTE TARGETS KILLED, AIRCRAFT LOST, AIRCRAFT IN REPAIR, AND AIRCRAFT AVAILABLE FOR NEXT DAY

GRAPHICS/PLOT MODULE
- DISPLAY RESULTS
- SIZE AIRCRAFT

P1 1157-8

VOUGHT

KEY ELEMENTS OF THE OPTIMIZATION PROCESS



PG-92B(1)-7

1. SELECTION OF INDEPENDENT VARIABLES

VOUGHT

VARIABLES AVAILABLE IN ASAP

WING PLANFORM VARIABLES

- AREA (FIXED OR CONSTANT WING LOADING)
- ASPECT RATIO
- THICKNESS RATIO
- TAPER RATIO
- SWEEP (QUARTER CHORD OR LEADING EDGE)

ENGINE VARIABLES

- ENGINE SCALE FACTOR (FIXED OR CONSTANT THRUST-TO-WEIGHT RATIO)
- BYPASS RATIO
- TURBINE INLET TEMPERATURE
- OVERALL PRESSURE RATIO
- SCHEDULING PARAMETER

MISSION VARIABLES

- PENETRATION DISTANCE
- PENETRATION ALTITUDE
- PENETRATION MACH NUMBER
- DISTANCE TO FEBA
- ORDNANCE WEIGHT
- NUMBER OF BOMBS
- LOITER TIME

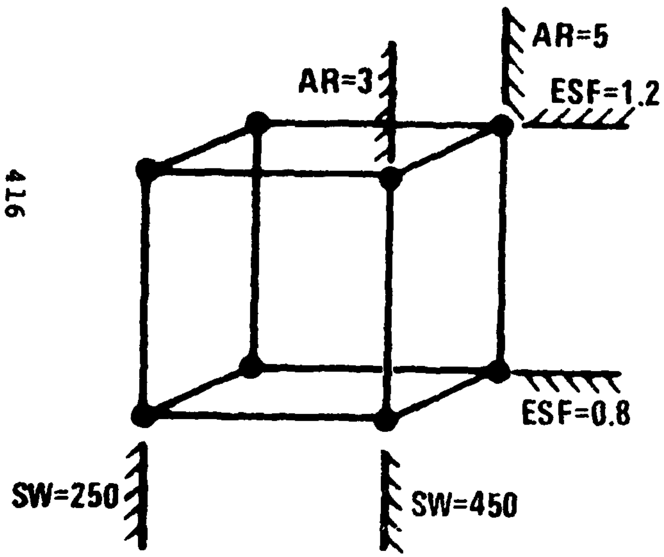
PG-928(1)-8

VOUGHT

2. DEFINE RESPONSE POINTS

DESIGN SPACE DEFINITION

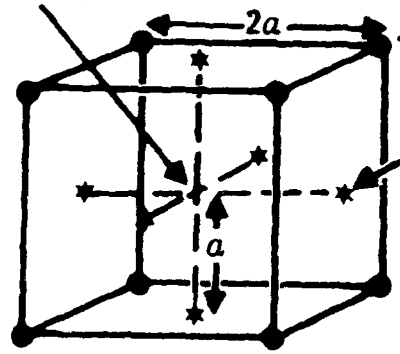
PARAMETRIC APPROACH



COMBINATIONS REQUIRED = 3^n
WHERE:

n = NUMBER OF INDEPENDENT VARIABLES

OPTIMIZATION APPROACH



MODIFIED COMPOSITE DESIGN

COMBINATIONS REQUIRED = $2^n + 2n + 1$

P6-920111-8

2. DEFINE RESPONSE POINTS

RESPONSE POINT REQUIREMENTS

NUMBER OF INDEPENDENT VARIABLES – n	PARAMETRIC/ FULL FACTORIAL 3^n	MODIFIED CENTRAL COMPOSITE DESIGN $2^n + 2n + 1$	LATIN SQUARE DESIGN $(n + 1)^2$	D-OPTIMUM DESIGN $\frac{(n+1)(n+2)}{2} + 1$
2	9	9	9	7
3	27	15	16	11
4	81	25	25	16
5	243	43	36	22
6	729	77	49	29
7	2,187	143	64	37
8	6,561	273	81	46
9	19,683	531	100	56
10	59,049	1,045	121	67
11	177,147	2,071	144	79
12	531,441	4,121	169	92
13	1,594,323	8,219	196	106
↓				
20	3,486,784,401	1,048,617	441	232

P6 978(1) 10

VOUGHT

4. ESTIMATE FUNCTION AND CONSTRAINT SURFACES

SECOND ORDER STEP-UP, STEP-DOWN REGRESSION

TO THE EQUATION:

$$Y = a_0 + a_1 x_1 + a_2 x_2 + \text{--} + a_n x_n + a_{11} x_1^2 + a_{12} x_1 x_2$$

$$+ \text{---} + a_{1n} x_1 x_n + a_{22} x_2^2 + a_{23} x_2 x_3 + \text{--} + a_{2n} x_2 x_n$$

$$+ \text{---} + a_{nn} x_n^2$$

TERMS ARE ADDED/DELETED TO MAXIMIZE CORRELATION

PS-828(1)-12

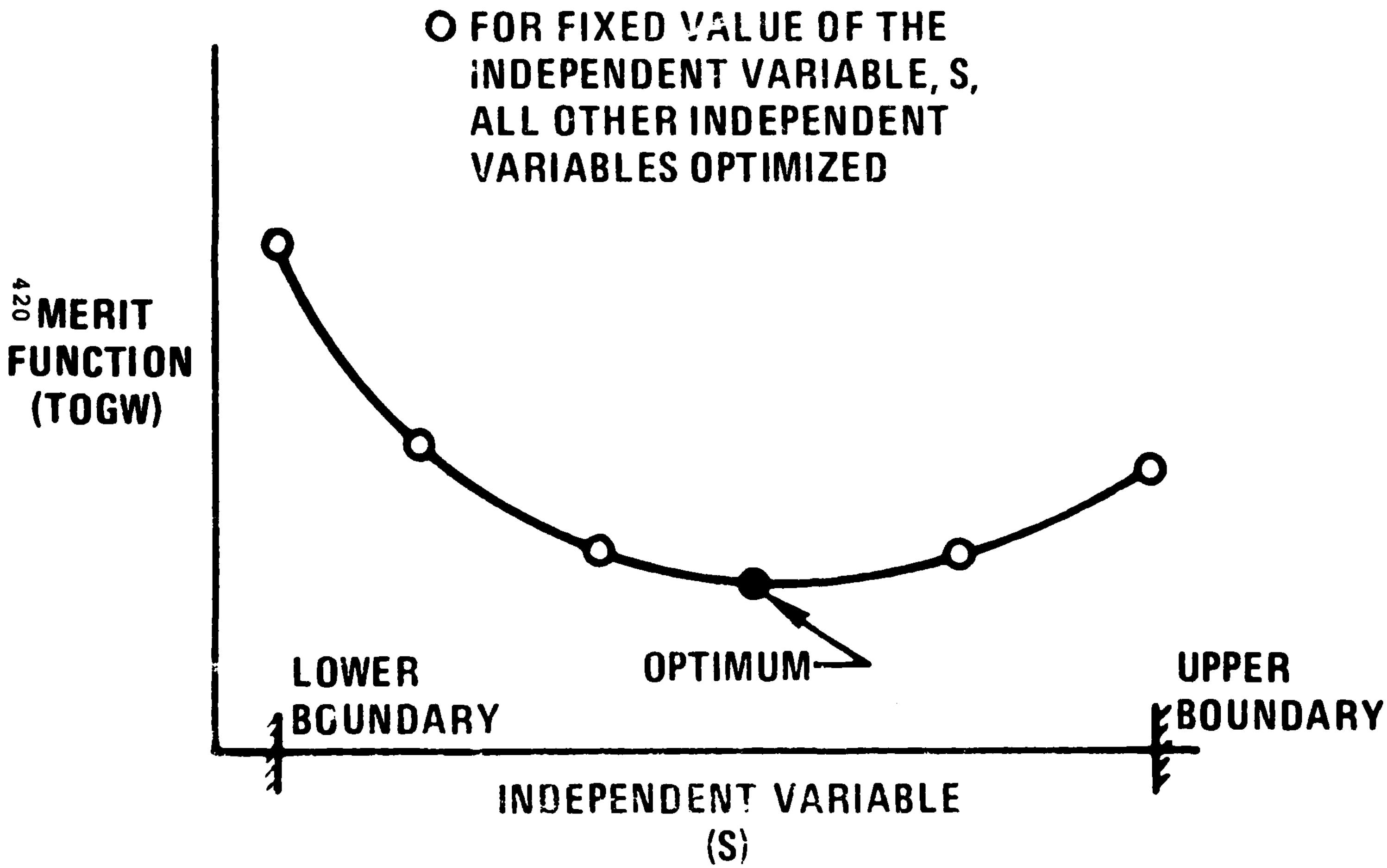
SEARCH TECHNIQUES

- **HILLEARY** – CONVENTIONAL GRADIENT (TANGENT PLANE) SEARCH
- **SIMPLEX** – GEOMETRIC SEARCH UTILIZING A FLEXIBLE $n + 1$ SIDED POLYGON IN n-SPACE

6. CONDUCT SENSITIVITY ANALYSIS

VOUGHT

BUCKET PLOT SENSITIVITY



VOUGHT

Design Concept Optimization Based on Integrated Effectiveness

ASAP

OPTIMIZATION MODULE

(Latin Square Selection)

↓

Configuration and Effectiveness Inputs

↓

CFEM Module

↓

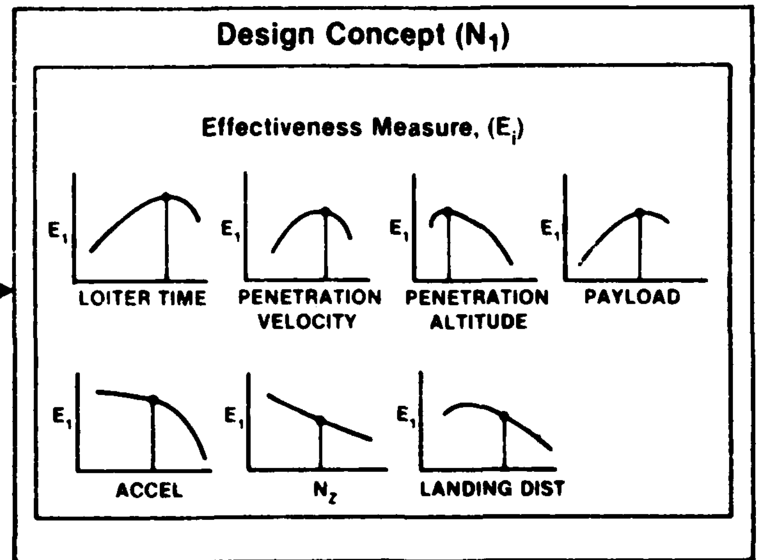
- Generalized Campaign Force Effectiveness Equation:

  $E_i = f\,(P_L, PH, PM, PD_1, PD_2, PD_3, NZ, TCS, T/W, W/S)$

- Hilleary Optimization Module gives:

  E_{OPT} as constrained by
  - Total program cost
  - Aircraft performance requirements
  - Mission performance requirements

→



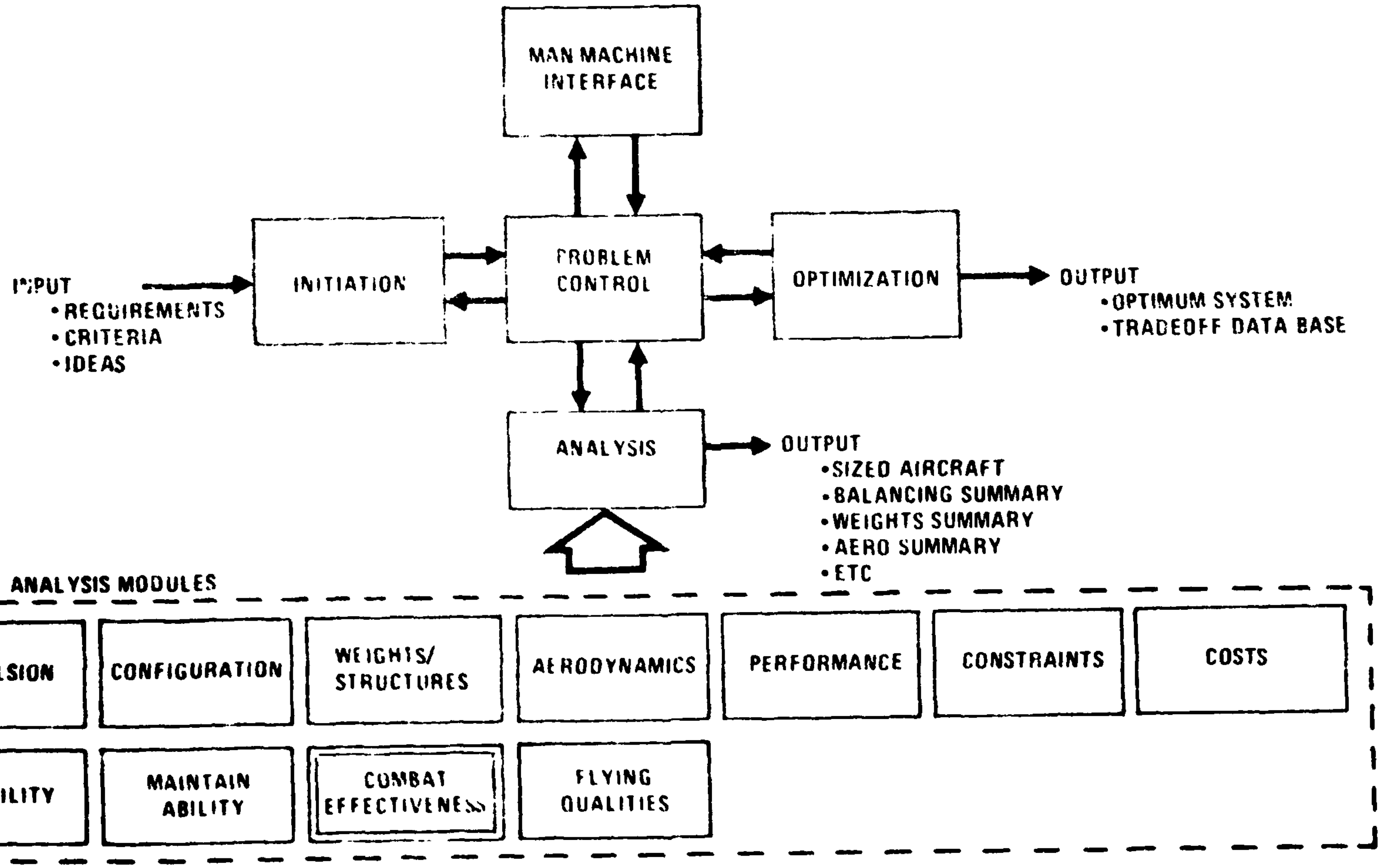
↓

Point Design and Evaluation

P1-1157-4

VOUGHT

AIRCRAFT SYNTHESIS ANALYSIS PROGRAM (ASAP)



VOUGHT

CFEM

- Evaluates the sortie generation capability of point design aircraft based on force attrition
- Examines the target kill effectiveness per sortie
- Computes the campaign force effectiveness in terms of percent targets killed in a given number of campaign days with a force size of fixed procurement cost

VOUGHT

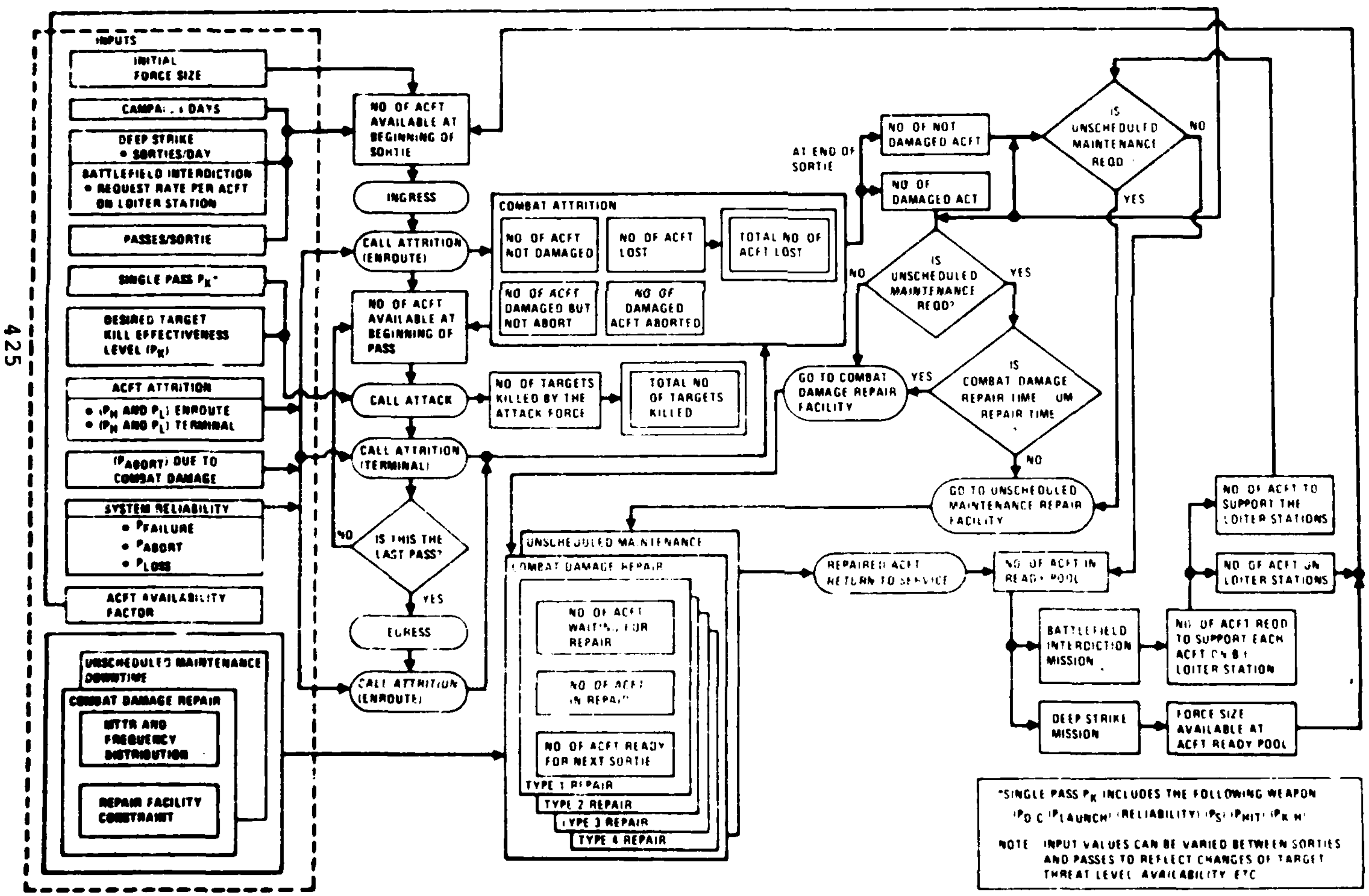
Force Attrition Is Sensitive to:

- Threat Scenario
- Mission Performance:
  - Penetration Distance over the Threat Area
  - Penetration Speed and Altitude
  - Weapon Delivery Standoff Distance
  - Defense Suppression
- Aircraft Vulnerability:
  - Probability of Hit by the Defense
  - Probability of Kill Given a Hit
  - Probability of Mission Abort Given a Hit
- Repair Capability:
  - Repair Downtime
  - Repair Facility Capacity

P1-1157-14

VOUGHT

COMBAT EFFECTIVENESS MODULE LOGIC FLOW DIAGRAM



P-8728(41)-13

COMBAT EFFECTIVENESS MODULE VOUGHT
DATA REQUIREMENTS

DATA REQUIRED	SOURCE
INITIAL FORCE SIZE	COST MODULE
NO. OF CAMPAIGN DAYS	INPUT
LENGTH OF OPERATIONAL DAY	INPUT
NO. OF SORTIES PER DAY	INPUT
TARGET DISTRIBUTION	INPUT TABLE
WEATHER DISTRIBUTION	INPUT TABLE
DESIRED TARGET KILL EFFECTIVENESS LEVEL, P_K	INPUT
ORDNANCE LOAD	PROBLEM CONTROL MODULE
PAYLOAD vs. RADIUS OR TOS	PERFORMANCE MODULE
AIRCRAFT ATTRITION	
• P_S SURFACE-TO-AIR ENROUTE*	INPUT TABLE FOR EACH THREAT
• P_S AIR-TO-AIR ENROUTE*	INPUT TABLE
• P_S SURFACE-TO-AIR TERMINAL*	INPUT TABLE
• THREAT DENSITY	INPUT
• THREAT RANGE	INPUT
• P_{ABORT} DUE TO COMBAT DAMAGE	INPUT
SYSTEM RELIABILITY	
• $P_{FAILURE}$	RELIABILITY MODULE
• P_{ABORT}	RELIABILITY MODULE
• P_{LOSS}	RELIABILITY MODULE
AIRCRAFT AVAILABILITY FACTOR	MAINTAINABILITY MODULE
COMBAT DAMAGE REPAIR	
• TIME DISTRIBUTION	INPUT TABLE
• FACILITY CONSTRAINT	INPUT
UNSCHEDULED MAINTENANCE REPAIR	
• TIME DISTRIBUTION	INPUT TABLE
• FACILITY CONSTRAINT	INPUT

*(ONE-ON-ONE ENGAGEMENT)

PS-920(11-17

VOUGHT

COMBAT EFFECTIVENESS MODULE OUTPUTS*

- NO. OF AIRCRAFT AVAILABLE AT BEGINNING OF EACH SORTIE (FOR STRIKE MISSION) OR AT BEGINNING OF EACH TIME-ON-STATION CYCLE (CAS/BI MISSION)
- NO. OF AIRCRAFT AVAILABLE TO CARRY OUT THE ATTACK
- AMOUNT OF ORDNANCE DELIVERED
- NO. OF TARGETS KILLED
- NO. OF AIRCRAFT LOST
- NO. OF WEAPONS LOST
- NO. OF AIRCRAFT DAMAGED
- NO. OF AIRCRAFT IN REPAIR (COMBAT DAMAGE)
- NO. OF AIRCRAFT IN REPAIR (UNSCHEDULED MAINTENANCE)
- NO. OF AIRCRAFT WAITING FOR REPAIR (COMBAT DAMAGE)
- NO. OF AIRCRAFT WAITING FOR REPAIR (UNSCHEDULED MAINTENANCE)
- TOTAL NUMBER OF PASSES PERFORMED (OR TOTAL NUMBER OF REQUESTS SATISFIED)

*(AS FUNCTION OF CAMPAIGN DAYS)

P0-020(1) 10

VOUGHT

ASAP/CFEM Data Flow

(1) Enroute Survival

(A) Against Surface-to-Air Defense:

$$\left[(P_s)_{SA}\right]_i = f(V, h, n_g, DSE, \ldots.)$$

V .... Penetration Velocity

h .... Penetration Altitude

n_g .... Maneuver 'g' Capability

DSE .... Defense Suppression Effectiveness

(B) Against Air-to-Air Defense:

$$\left[(P_s)_{AA}\right] = f(V, h, T/W, W/S, TWC, \ldots.)$$

T/W .... Thrust-to-Weight Ratio

W/S .... Wing Loading

TWC .... Threat Warning Capability

VOUGHT

ASAP/CFEM Data Flow (cont)

(2) TERMINAL SURVIVAL

- Against Surface-to-Air Defense

  $\left[(P_s)_T\right]_i = f(V, h, n_g, DSE, D_s, \ldots)$

  D_s .... Standoff Distance

(3) FORCE ATTRITION

- Expected No. of Aircraft Lost
- Expected No. of Aircraft Damaged
- Force Size Available for Next Mission

VOUGHT

ASAP/CFEM Data Flow (cont)

(4) TARGET KILL EFFECTIVENESS

- Expected No. of i-Type Targets Killed per Pass:

$$\left[(T_K)_p\right]_i = f(R, W_{PL}, D_S, P_{d/A}, CEP, R_L, ...)$$

R .... Mission Radius

W_{PL} .... Payload Capability

D_S .... Standoff Distance

$P_{d/A}$ .... Target Detection and Acquisition Probability

CEP .... Weapon Delivery Accuracy

R_L .... Weapon Lethal Radius

(5) CAMPAIGN FORCE EFFECTIVENESS MEASURE

(A) Force Size Required To Kill Given Targets in Specified No. of Campaign Days

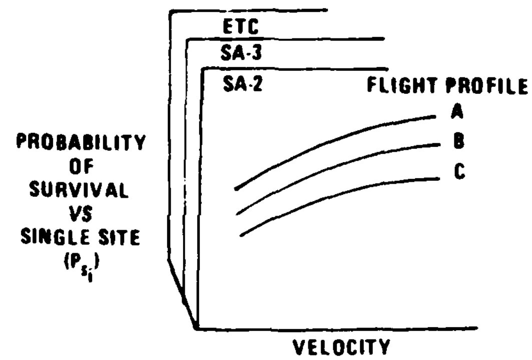
(B) Percent Targets Killed by a Given Force Size at Equal Program Cost and Campaign Days

P1-1157-7

VOUGHT

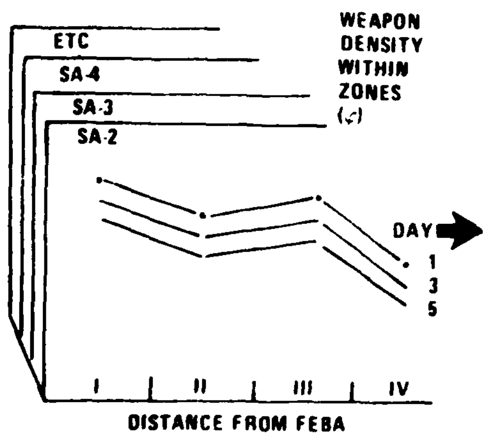
SCENARIO DATA APPLICATION (ENROUTE SURVIVABILITY)

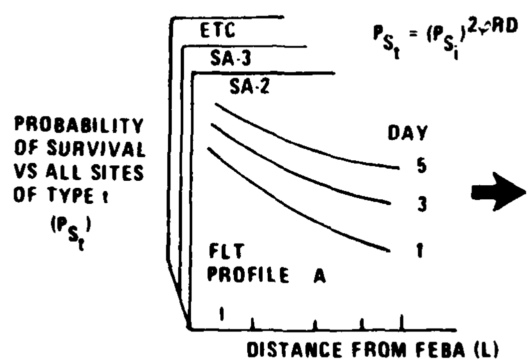
SURFACE TO AIR WEAPONS	NOS IN ZONE			
	I	II	III	IV
SA-2	n_{11}	n_{12}	n_{13}	n_{14}
SA-3	n_{21}	n_{22}	n_{23}	n_{24}
SA-4	n_{31}	n_{32}	n_{33}	n_{34}
SA-6	n_{41}	n_{42}	n_{43}	n_{44}
ETC				

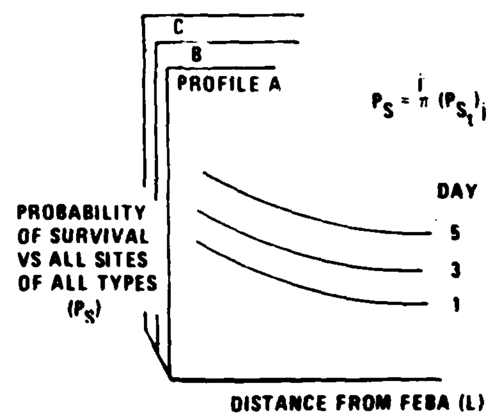


NOTES:

- φ IS MODIFIED BY AN AVAILABILITY FACTOR RELATED TO OPERATIONAL CONCEPT, i.e., RE % SHUTDOWN OR MOVING
- NO. OF SITES DECREASES WITH TIME DUE TO ATTRITION, LOGISTICS, ETC. TYPICAL ASSUMPTION: ONLY 50% OF SURVIVING SITES OF PREVIOUS DAY SURVIVE PER DAY.



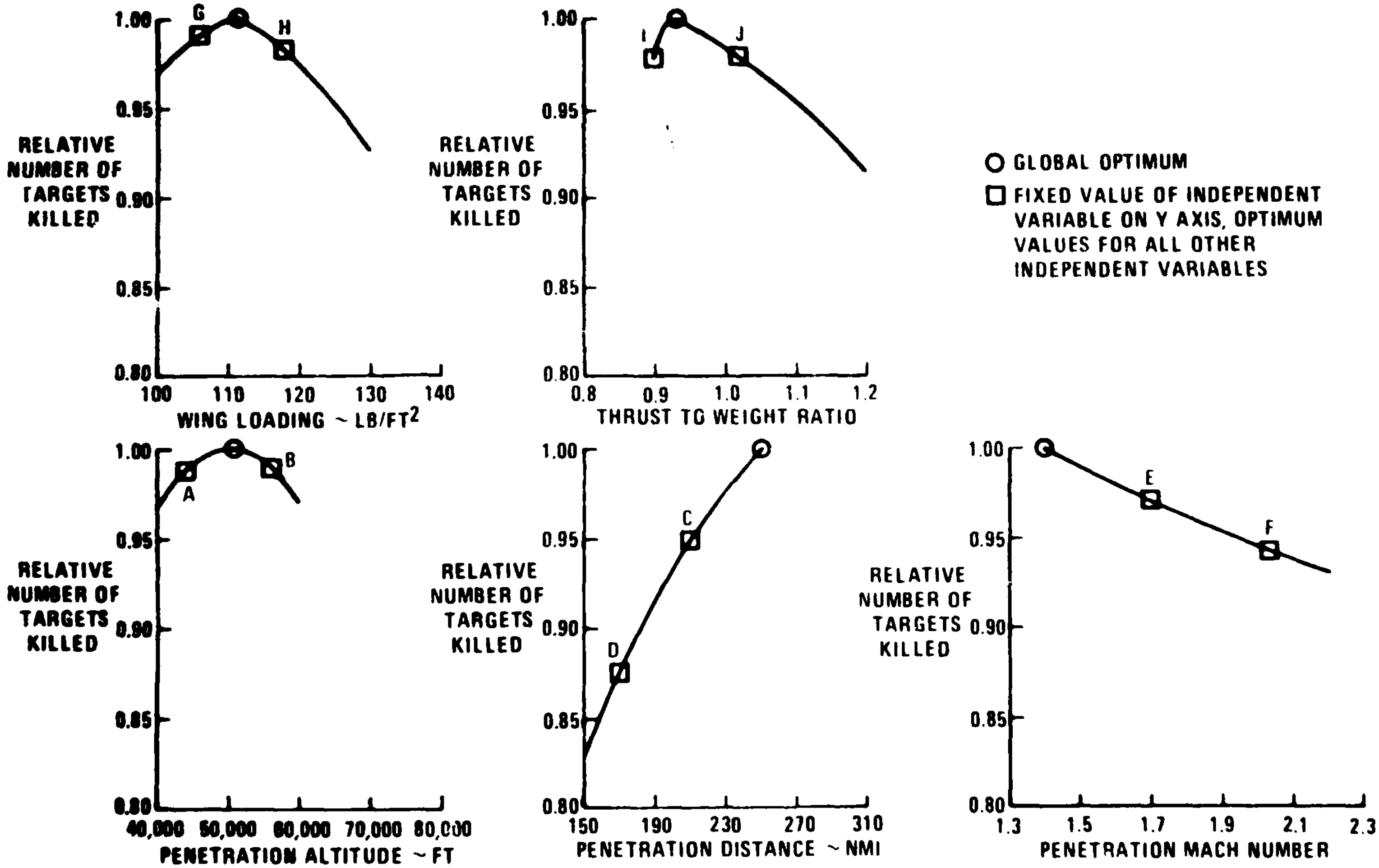




P6-338-2

VOUGHT

LONG-RANGE STRIKE SENSITIVITY DATA

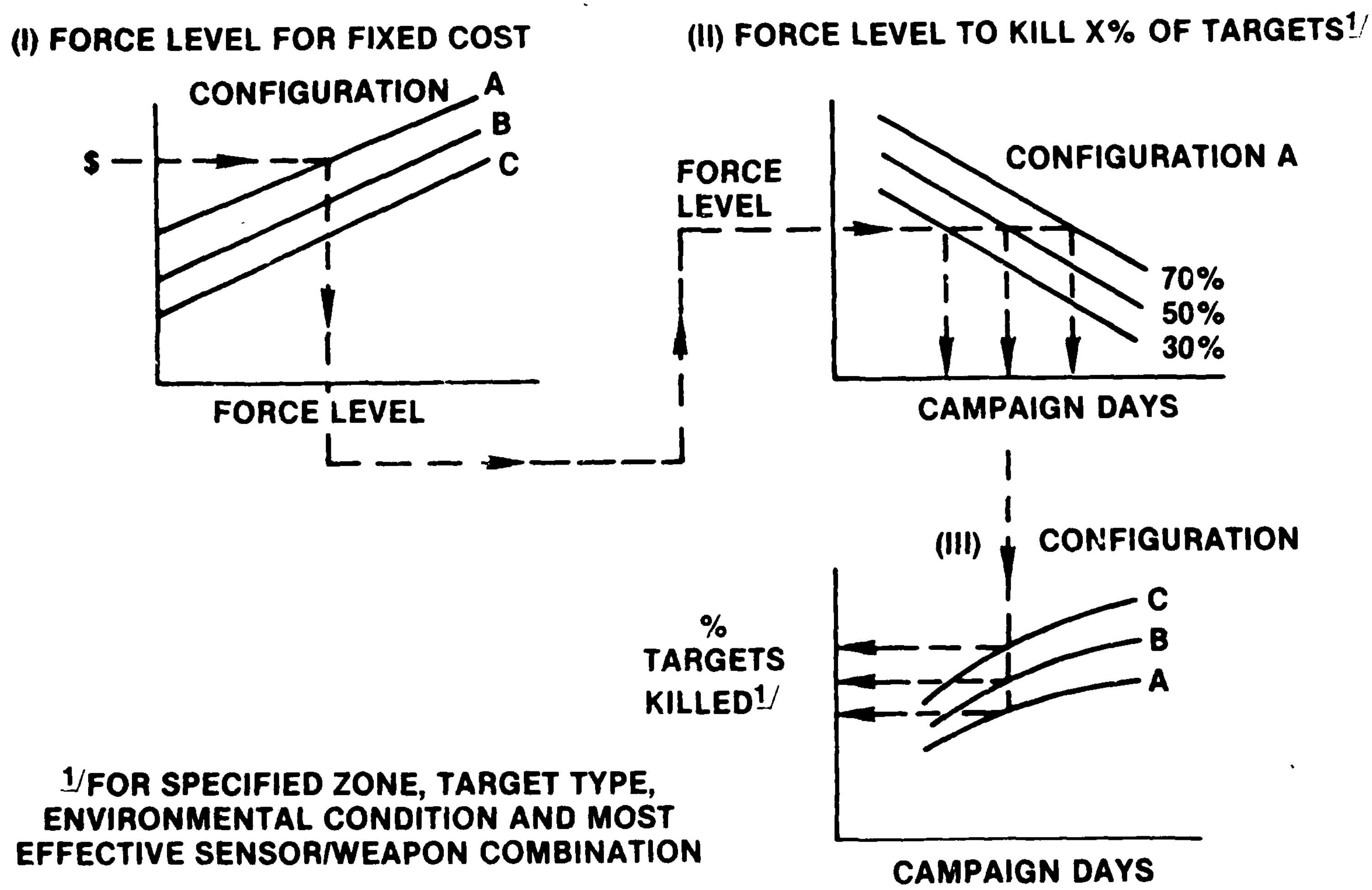


P6-02B(1)-23

VOUGHT

Cost Effectiveness Comparisons

Effectiveness/Fixed Cost



1/FOR SPECIFIED ZONE, TARGET TYPE, ENVIRONMENTAL CONDITION AND MOST EFFECTIVE SENSOR/WEAPON COMBINATION

P1-1157 3

VOUGHT

WHAT IS THE MOST EFFECTIVE AIRCRAFT?

	CONFIGURATION										
	A	B	C	D	E	F	G	H	I	J	OPTIMUM
PENETRATION ALTITUDE ~ FT	44,000	56,000	48,140	45,687	54,050	57,540	50,680	50,370	50,840	50,870	50,800
PENETRATION DISTANCE ~ NMI	250	250	210	170	250	250	250	250	250	250	250
PENETRATION MACH NUMBER	1.4	1.4	1.4	1.4	1.72	2.04	1.4	1.4	1.64	1.4	1.40
WING LOADING ~ LB/FT^2	110.0	111.5	112.7	113.9	110.2	111.5	106	118	110.0	118.7	111.4
THRUST LOADING	0.919	0.937	0.949	0.967	0.900	0.900	0.932	1.011	0.900	1.02	0.931
NUMBER OF TARGETS KILLED	0.987	0.989	0.948	0.874	0.969	0.942	0.991	0.983	0.976	0.978	1.000
NUMBER OF AIRCRAFT LOST	1.003	0.998	0.933	0.923	0.815	0.677	0.992	0.976	0.862	0.974	1.000
NUMBER OF AIRCRAFT IN REPAIR	0.990	0.999	0.931	0.922	0.998	0.998	0.992	0.987	0.996	0.986	1.000
NUMBER OF AIRCRAFT NEXT DAY	0.982	0.998	1.135	1.192	1.007	1.016	0.994	0.983	1.000	0.983	1.000
TAKEOFF GROSS WEIGHT	1.040	1.004	0.953	0.903	1.119	1.221	1.007	1.012	1.101	1.012	1.000
FLYAWAY COST	1.013	1.004	0.982	0.963	1.042	1.080	1.009	1.010	1.035	1.012	1.000
FORCE SIZE (UE)	0.987	0.998	1.019	1.039	0.960	0.921	0.993	0.984	0.967	0.982	1.000
LANDING GROUND ROLL	0.996	1.000	1.010	1.020	0.988	0.999	0.959	1.053	0.988	1.058	1.000
EQUILIBRIUM N_Z – 30K, MN = 0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.031	1.0	1.0	1.0	*1.000
ACCELERATION TIME – 0.85 TO 1.6, 30K	1.0	0.998	1.0	1.0	0.988	0.929	1.0	0.840	1.0	0.826	*1.000

▭ HELD CONSTANT
* SIZING CRITERIA

P0-828(1)-24

Conclusions

- Mission performance effectiveness is highly sensitive not only to aircraft survivability, but also to combat damage, unscheduled maintenance, reliability, and repair downtime. Consequently, their contributions would have to be considered in the design selection process. CFEM can be used in performing such task.

- ASAP/CFEM is an effective computer-aided design tool. It has been applied to many of Vought's aircraft programs.

P1-1157-13

AIRCRAFT DESIGN FOR SURVIVABILITY
AND VULNERABILITY

Jerry Wallick
Chairman, JTCG/AS
Survivability Assessment Subgroup

AIRCRAFT DESIGN FOR SURVIVABILITY
AND VULNERABILITY

Jerry Wallick
Chairman, JTCG/AS
Survivability Assessment Subgroup

NOTE: Narrative numbers refer to circled vugraph numbers (lower right corner)

1. I will be presenting a two part briefing on the procedures used in the Air Force, Aeronautical Systems Division to design aircraft for survivability. Part I addresses current procedures for specifying survivability/vulnerability (S/V) requirements, while Part II is a summary presentation of an initiative to revise our current procedures and make specifications tailorable at the system level for S/V.

2. In Part I, I will overview current procedures and give some examples on how the Air Force requirements for S/V, both nuclear and non-nuclear, are arrived at and specified.

3. AFR 80-38 is the regulation designating responsibilities within the Air Force for implementing the survivability program, both technology development and system application. The regulation outlines what must be done rather than how to do it. For the most part, the Air Force Systems Command and the subordinte Acquisition Division (Aeronautical Systems Division for aircraft) then implement S/V programs on specific systems to assure that requirements are established and met.

4. AFR 80-38 defines the buzz words as shown here. I would point out that a major problem for S/V engineers when dealing with non-S/V discipline oriented engineers and managers is the distinction between survivability and vulnerability. The best way to make this distinction is to keep in mind that vulnerability is a subset of survivability, not the inverse probability. System survivability must consider vulnerability as well as characteristics associated with detectability, tactics, performance (speed and maneuverability), and countermeasures (active and passive).

5. Within the Air Force Systems Command the Weapons Laboratory is designated as the lead laboratory for nuclear and laser survivability technology development. This viewgraph lists the AFWL responsibilities in support of this technology development.

6. This viewgraph summarizes types of threats and nuclear threat kill mechanisms that form the basis of nuclear survivability requirements. Generally, nuclear requirements reduce to specification of hardness levels against the listed threat mechanisms. Based on postulated threats, missions of the system, and availability of technology, the S/V engineer establishes hardness requirements which represent a balance among the various threat mechanisms.

7. Moving on to non-nuclear S/V considerations, this viewgraph depicts a simplification of the problem we face. However, this is precisely the procedure found in captured North Vietnamese foot solider manuals defining how to shoot down U.S. aircraft in Southeast Asia.

8. This is the result of following the manual.

9. The Flight Dynamics Laboratory is designated the Air Force Systems Command lead laboratory for non-nuclear S/V technology development. This viewgraph outlines the AFWAL/FDL responsibilities in support of this technology development.

10. Types of threats and nonnuclear threat kill mechanisms, which are considered in establisning non-nuclear survivability requirements, are summarized. However, since non-nuclear threat effects are more point oriented (as compared to area coverage of nuclear weapons), specification of hardness requirements is not sufficient to adequately define system survivability except in the rare case where mission requirements are such that detection, tracking, and guidance by the threat are practically certain. The examples of current requirements, shown later, are for a system that must fly into the threat like this. The purpose of Part II of my presentation is to outline our apporach to addressing this problem.

11 & 12. These two viewgraphs show the AFWAL/FDL gunfire test facility at Wright-Patterson AFB, Ohio. In this facility it is possible to test full-scale sections of aircraft or missiles to impact by single fragments, multiple fragments, armor piercing projectiles, and high explosive projectiles up through 23 mm, under airflow conditions up to about 450 knots.

13. The Combat Data Information Center (CDIC) is a contractor-operated repository for non-nuclear combat data. CDIC is a DOD facility currently funded jointly by the JTCG/AS and JTCG/ME. A more detailed description of the CDIC can be found in the brochure handed out at the Workshop registration table. If you did not get one at

registration, the Air Force manager for CDIC is Mr. Gary Streets, AFWAL/ FIES, WPAFB, Ohio 45433. The telephone number is (513) 255-4840 or autovon 785-4840.

14, 15, & 16. These viewgraphs are a series of gun camera photographs showing an F-4 aircraft encountering an SA-2 in Southeast Asia. This is an example of one type data available at CDIC.

17. Shown here are the elements of a typical non-nuclear S/V program for a system. The intent is to show how threat, operational parameters, system vulnerability, and survivability requirements are iteratively considered, analyzed, and tested to arrive at a "survivable system." Development of appropriate or adequate survivability requirements can be seen as a complex and, at times, painful iteration of many factors which may become very subjective. As the discipline matures it is hoped that some of this subjectivity will be removed. Recent developments in methodology, data bases, and test procedures are fundamental to correcting this problem, and successful implementation of the specifications is discussed later in Part II.

18. This viewgraph outlines the current procedure for defining nuclear survivability requirements. You will note here that the Air Force uses the Nuclear Criteria Group, a general officer level group at Air Staff level, to define free-field nuclear environments which serve as the basis for system requirements. As you will recall, specification of nuclear S/V requirements has historically taken the form of designing to hardness levels. Although not a trivial task for the designer, specification of the requirement has been somewhat easier and more quantifiable than for non-nuclear requirements.

19 & 20. These viewgraphs are a kind of checklist for parameters and relationships for factors to consider in establishing requirements for non-nuclear S/V system and subsystem specifications. As might be expected from previous comments on the complexity of defining non-nuclear requirements, the specifications most applicable to aircraft design are those addressing signatures, performance and kill probability (i.e., reducing the probability of kill given a hit).

21. Shown here are A-10 design requirements for nonnuclear survivability and a summary of demonstrated hardness. Shaded areas labeled "demonstrated" have been subjected to testing at the threat level specified or have been analytically evaluated to assure that those subsystems have

indeed been designed to withstand a single impact from that threat.

22 & 23. These viewgraphs outline current analytical methods used at ASD to assess aircraft survivability and vulnerability and the considerations included. As can be seen, current methods use rather detailed level of design information. This is one area where I feel a considerable amount of work needs to be done in order for survivability to be fully integrated into computer-aided design. Methods, data, and S/V engineering should interface with conceptual and preliminary designers to effectively make S/V a "cradle to grave" system engineering discipline.

24. In Part II of my presentation, I would like to outline a project we are undertaking at ASD, Deputy for Engineering, which has the potential to correct some of the problems we have heard defined at this workshop by industry regarding inadequacy of definition of specific S/V requirements by services. This project, although being worked by the Air Force, has been briefed at DOD level and the eventual intent is to put the documentation into a MIL-STD for full coordination.

25. The total ASD initiative encompasses the entire system specification writing effort, of which the S/V document, Aeronautical Systems Mission Completion in a Combat Environment, is one of approximately 150 documents, which are intended to replace over 9100 specifications and standards now in use by the Air Force in writing and specifying system requirements. Each separate discipline will be writing a MIL-PRIME document, in the form of a specification or standard, stating requirements (with blanks to be filled in as the specification is tailored). It will be accompanied by a MIL-HANDBOOK which is to provide technical back-up, rationale, and lessons learned for use by the engineers in tailoring the specification.

26. This is a list of the concerns addressed in the draft MIL-STD we have developed for S/V.

27. The operational needs are addressed as primary and secondary mission requirements associated with initial day and subsequent days of the war. In addition, there are provisions for specifying post-combat availability, such as battle damage repair time, of several time dependent categories.

28, 29, & 30. These viewgraphs are excerpts of some of the actual requirements of section 3 and validation procedures of section 4 from the draft MIL-STD.

31. Currently we have developed a draft of the MIL-STD which is in technical review by ASD. Mr. Dudley Ward (ASD/ENFTV) is identified as the primary engineer for the S/V MIL-STD and HANDBOOK. We are approximately 25 percent of the way through development of a draft HANDBOOK which is scheduled for completion in June 1981. Much of the information for the HANDBOOK is being derived from the current JTCG/AS S/V Handbook and from AFSC Design Handbook 2-7. In addition, other JTCG/AS and Defense nuclear documents are being used as resources.

32 & 33. These viewgraphs give an indication of how far we have come in the S/V area, particularly from the standpoint of fuel system arrangement and protection against non-nuclear threats. The DeHavilland 4 was known as the flying coffin. Ground troops were instructed to aim at the pilot to shoot it down. However, it was not too critical to hit the pilot since the fuel tank was right behind the pilot and as often as not, aircraft kill was caused by a fire or explosion of the hit fuel tank. As "contrasted to the advanced technology used in the F-4" where (again) the fuel tank was installed right against the Guy in Back, again the same problems existed. In the F-4 we had to resort to accepting the penalty of parasitic protection to achieve "acceptable" attrition rates for the aircraft when we went to war.

34. I feel we have had a good three days of interaction between S/V engineers and analysts and system designers this should set the stage for further formal efforts to integrate S/V design into the aircraft conceptual and preliminary design cycle. The total team running in the race can have extremely beneficial payoff as opposed to the brute force method we currently use for getting S/V into the system as an off-the-track (more precisely off-line) or after-the-fact fix-up of weapon systems.

AIRCRAFT DESIGN FOR SURVIVABILITY AND VULNERABILITY

PRESENTER:
JERRY WALLICK
AERONAUTICAL SYSTEMS DIVISION

1

PART I

CURRENT SYSTEMS

MANAGEMENT OF THE
AIR FORCE SURVIVABILITY PROGRAM — AFR 80-38 . . .

INSURES THAT . . .

a. AIR FORCE SYSTEMS AND MISSION EQUIPMENT ARE CAPABLE OF SURVIVING THE EFFECTS OF A MAN-MADE HOSTILE ENVIRONMENT.

b. SURVIVABILITY IS FULLY CONSIDERED IN EACH USAF SYSTEM PROGRAM DURING THE ACQUISITION LIFE CYCLE.

c. SYSTEM SURVIVABILITY IS REEVALUATED THROUGHOUT THE ACQUISITION LIFE CYCLE OF EACH SYSTEM WHEN EITHER THE HOSTILE ENVIRONMENT, THE SYSTEM, OR THE MISSION IS ALTERED.

d. SYSTEM HARDNESS IS MAINTAINED THROUGHOUT THE ACQUISITION LIFE CYCLE OF EACH SYSTEM.

3

TERMINOLOGY

SURVIVABILITY—THE CAPABILITY OF A SYSTEM TO AVOID AND WITHSTAND A MANMADE HOSTILE ENVIRONMENT WITHOUT SUFFERING ABORTIVE IMPAIRMENT OF ITS ABILITY TO ACCOMPLISH ITS DESIGNATED MISSION

VULNERABILITY—THE CHARACTERISTICS OF A SYSTEM WHICH CAUSE IT TO SUFFER A FINITE DEGRADATION (INCAPABILITY TO PERFORM THE DESIGNATED MISSION) AS A RESULT OF HAVING BEEN SUBJECTED TO A CERTAIN LEVEL OF EFFECTS IN A MAN-MADE HOSTILE ENVIRONMENT.

HARDNESS—A MEASURE OF THE ABILITY OF A SYSTEM TO WITHSTAND EXPOSURE TO ONE OR MORE OF THE EFFECTS OF EITHER NUCLEAR OR NONNUCLEAR WEAPONS.

4

AIR FORCE WEAPONS LABORATORY

(NUCLEAR & LASER S/V)

- NUCLEAR WEAPONS EFFECTS (NWE) PROGRAMS
- NWE TECHNOLOGY DATA BASE
- NUCLEAR ENVIRONMENT SIMULATION & TESTING
- NUCLEAR HARDNESS ASSESSMENT TECHNIQUES
- SIMILAR CAPABILITIES FOR LASER S/V TECHNOLOGY

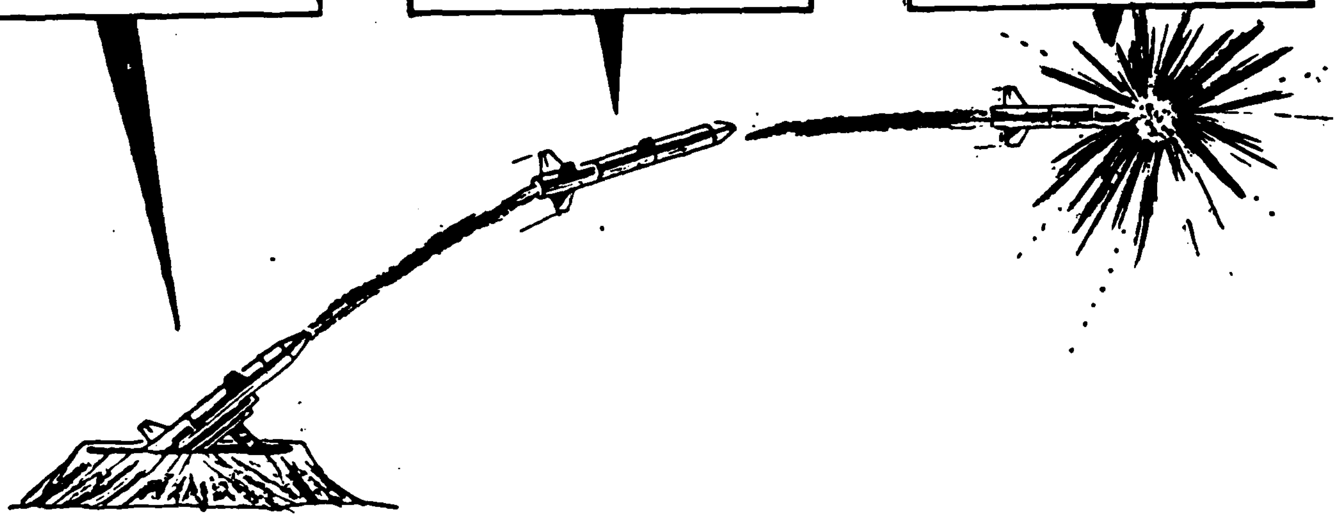
5

NUCLEAR THREATS

GENERAL THREATS
- ICBM
- SLBM
- AAM
- SAM

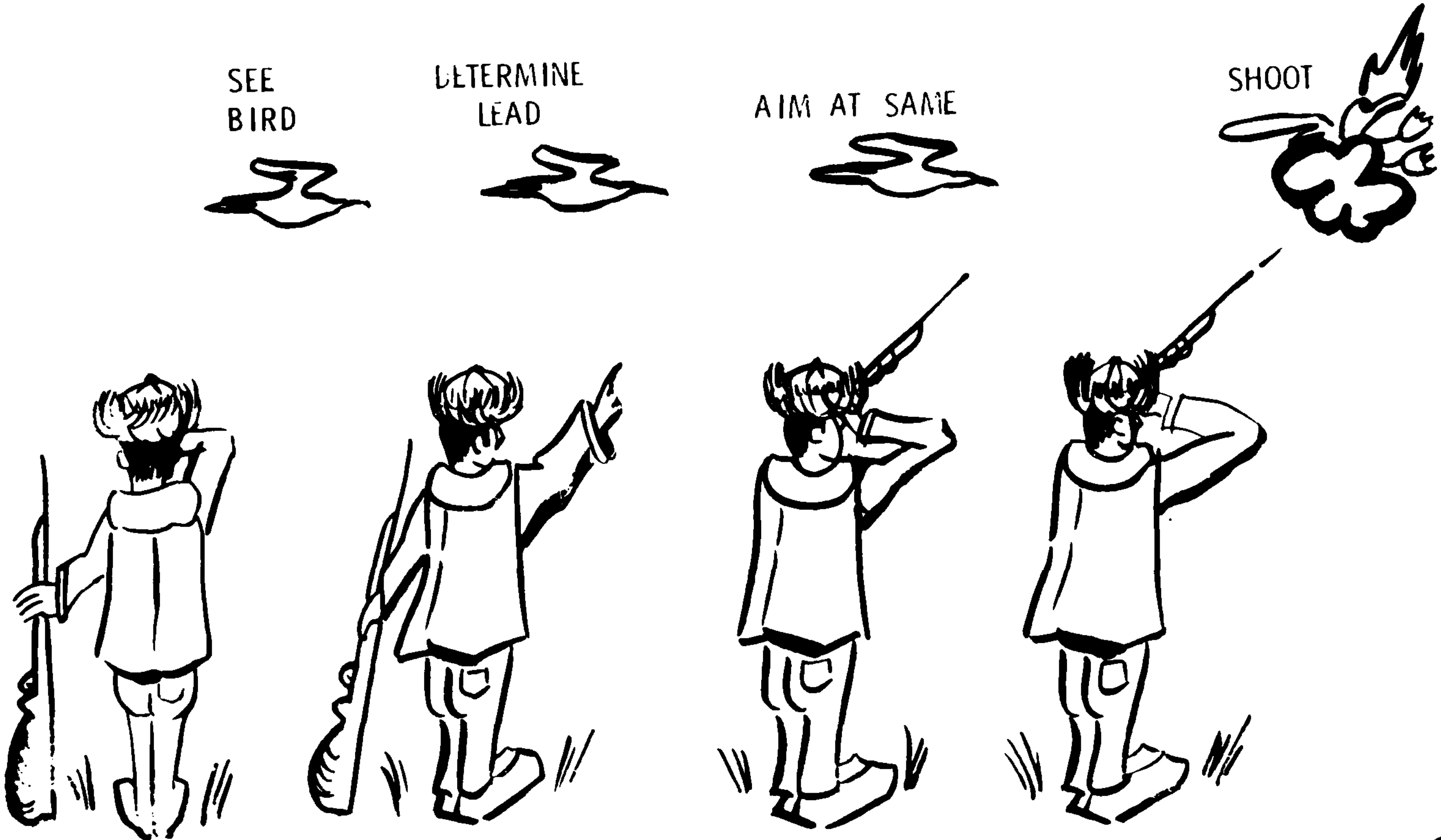
WARHEAD DESCRIPTORS
- Kilotons

THREAT MECHANISMS
- Blast
- Thermal
- Transient Radiation
- Electro Magnetic Pulse (EMP)



6

OPEN SEASON
(WAR)



7

"No, it was not I who brought down your great screaming bird—someone else must have thrown the rock!"

(8)

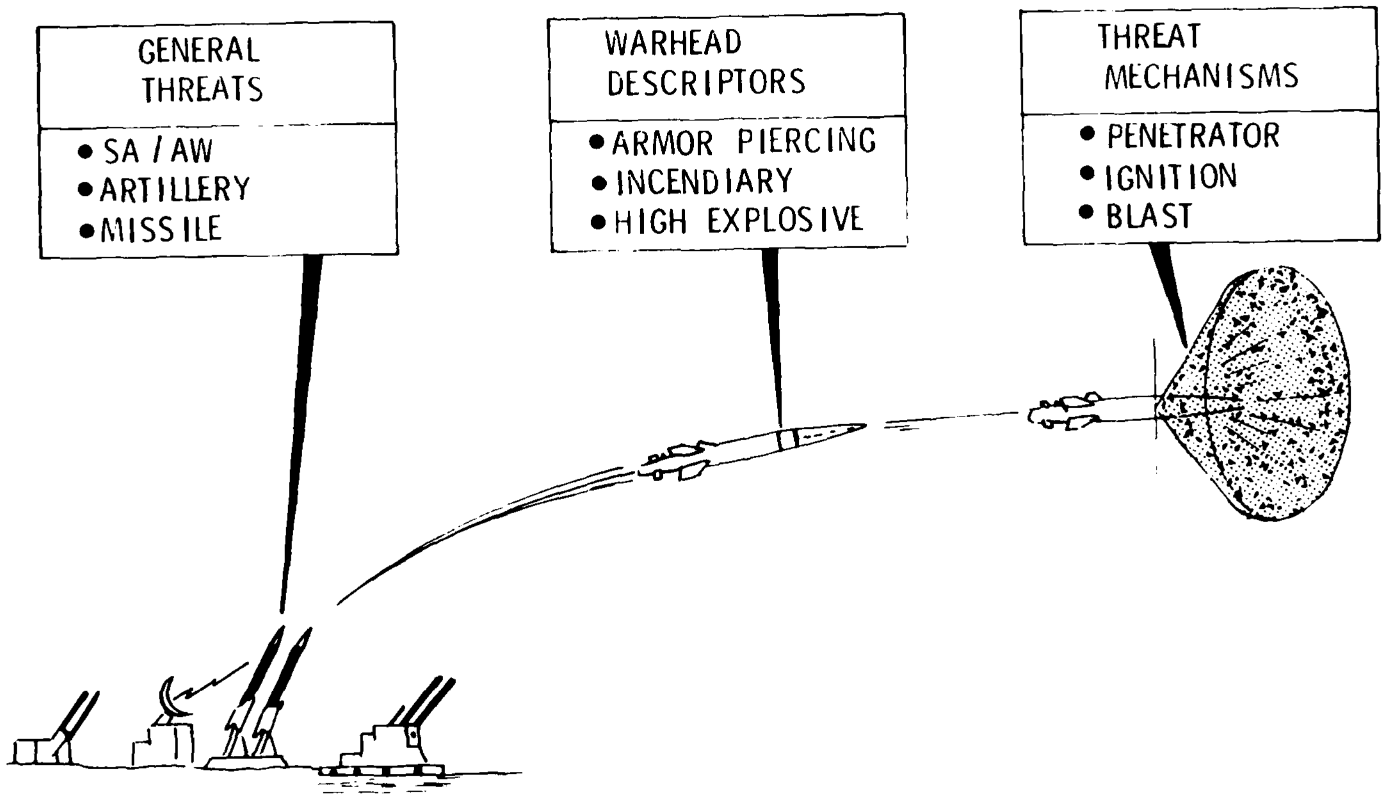
AIR FORCE FLIGHT DYNAMICS LABORATORY

(NONNUCLEAR S/V)

- NONNUCLEAR SURVIVABILITY TECHNOLOGY DEVELOPMENT
- NONNUCLEAR WEAPONS EFFECTS DEFINITION
- TEST METHODS & TEST INSTRUMENTATION
- THREAT SIMULATION & TESTING
- EXPERIMENTAL DATA BASE
- COMBAT DATA (CDIC)

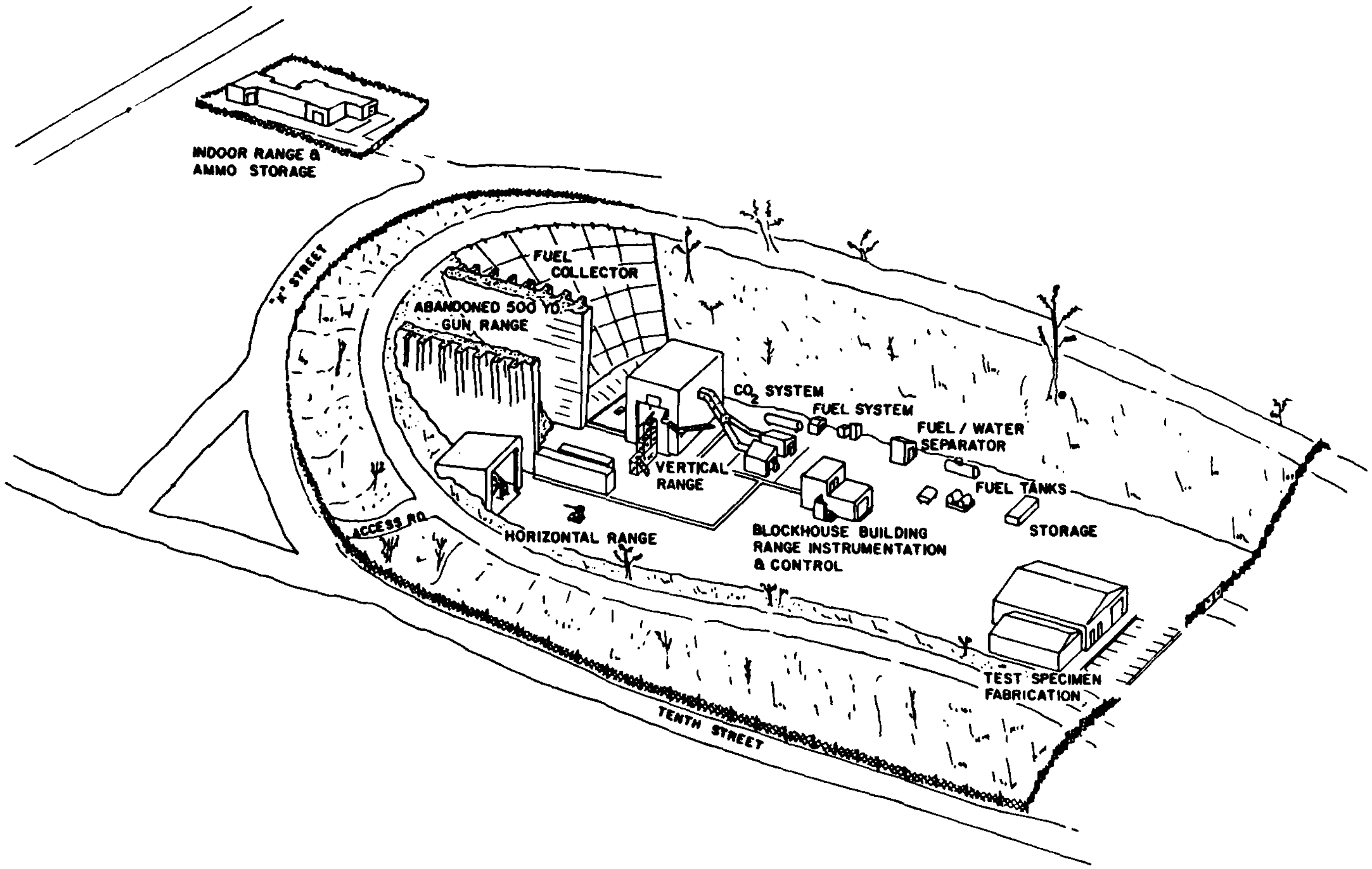
9

NON-NUCLEAR THREATS



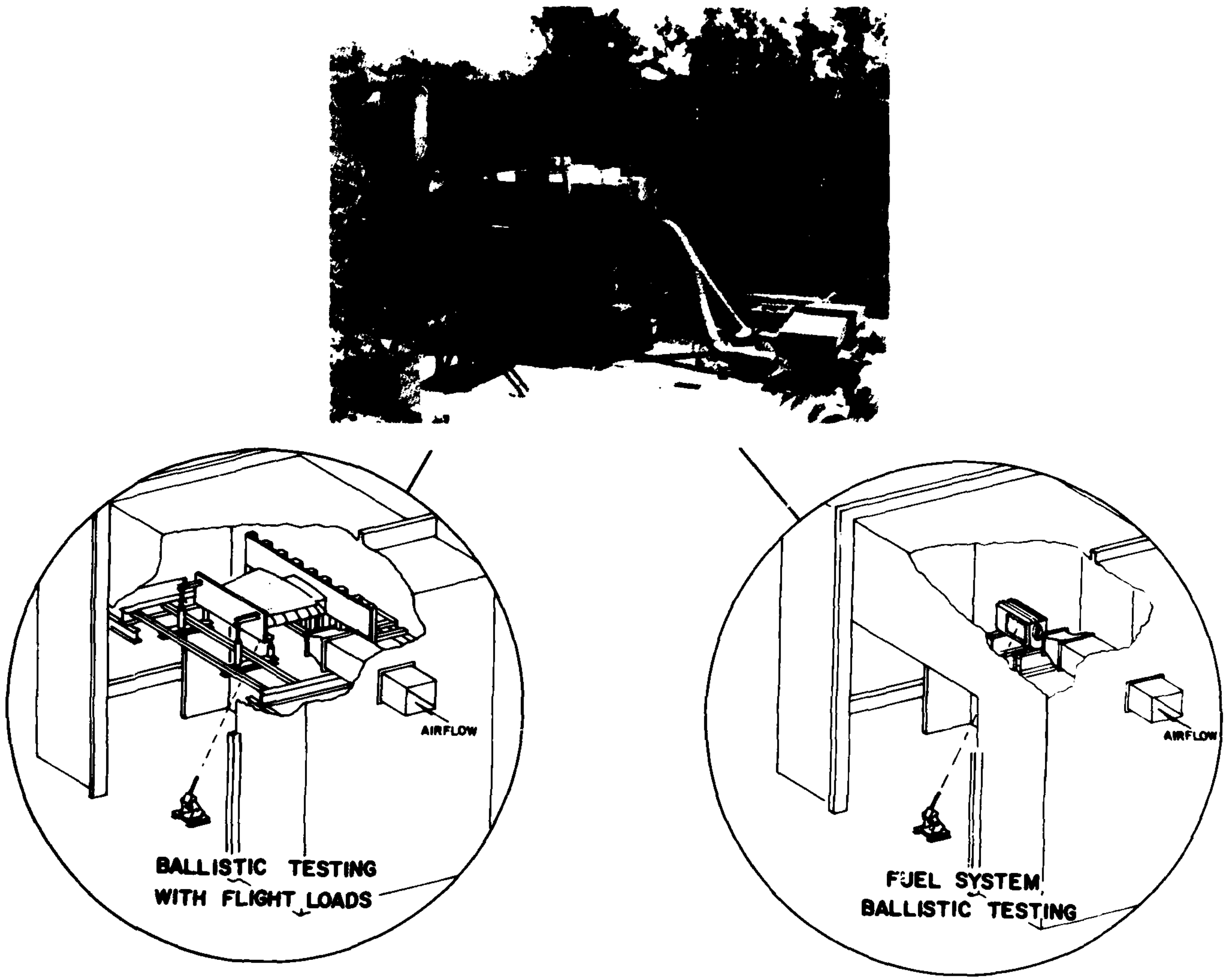
10

AIRCRAFT SURVIVABILITY RESEARCH FACILITY



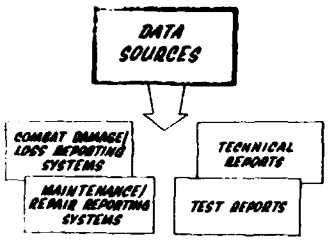
11

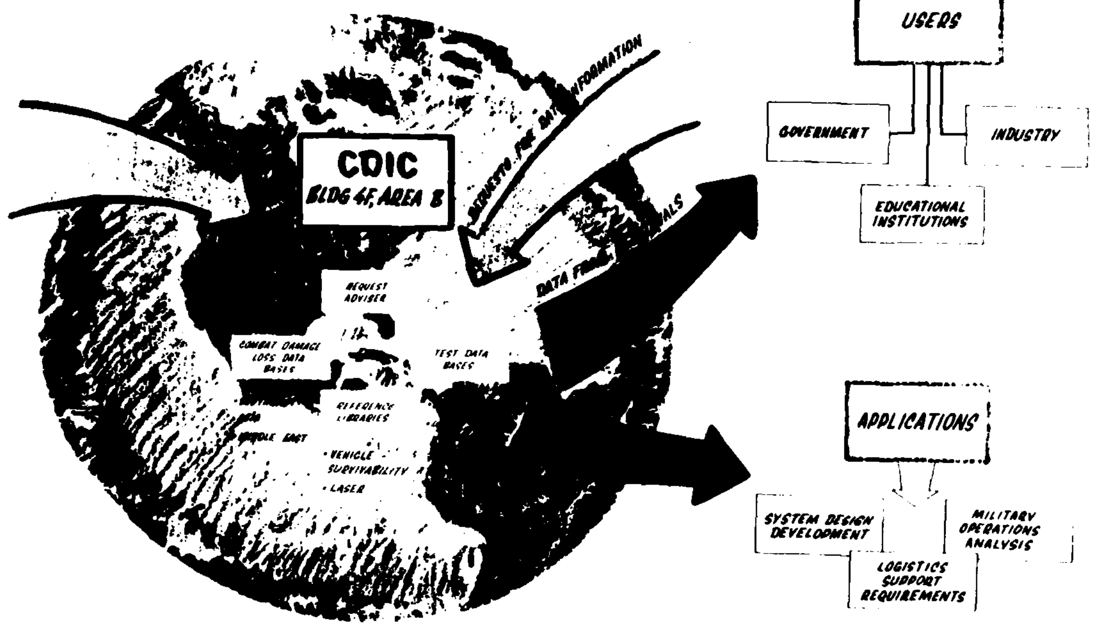
VERTICAL RANGE CAPABILITIES



(12)

COMBAT DATA INFORMATION CENTER (CDIC)





PURPOSE

CDIC IS THE CENTRAL REPOSITORY AND DATA DISSEMINATION CENTER FOR COMBAT, COMBAT-RELATED, OPERATIONAL AND TEST DATA WHICH CAN BE UTILIZED IN AIRCRAFT, SHIP AND GROUND VEHICLE SURVIVABILITY, VULNERABILITY, MAINTENANCE, LOGISTICS AND MILITARY OPERATIONS STUDIES

DIRECTED BY

FLIGHT DYNAMICS LABORATORY, AFWAL/FIES

SPONSORED BY

JTCG/AS AND JTCG/ME

OPERATED BY

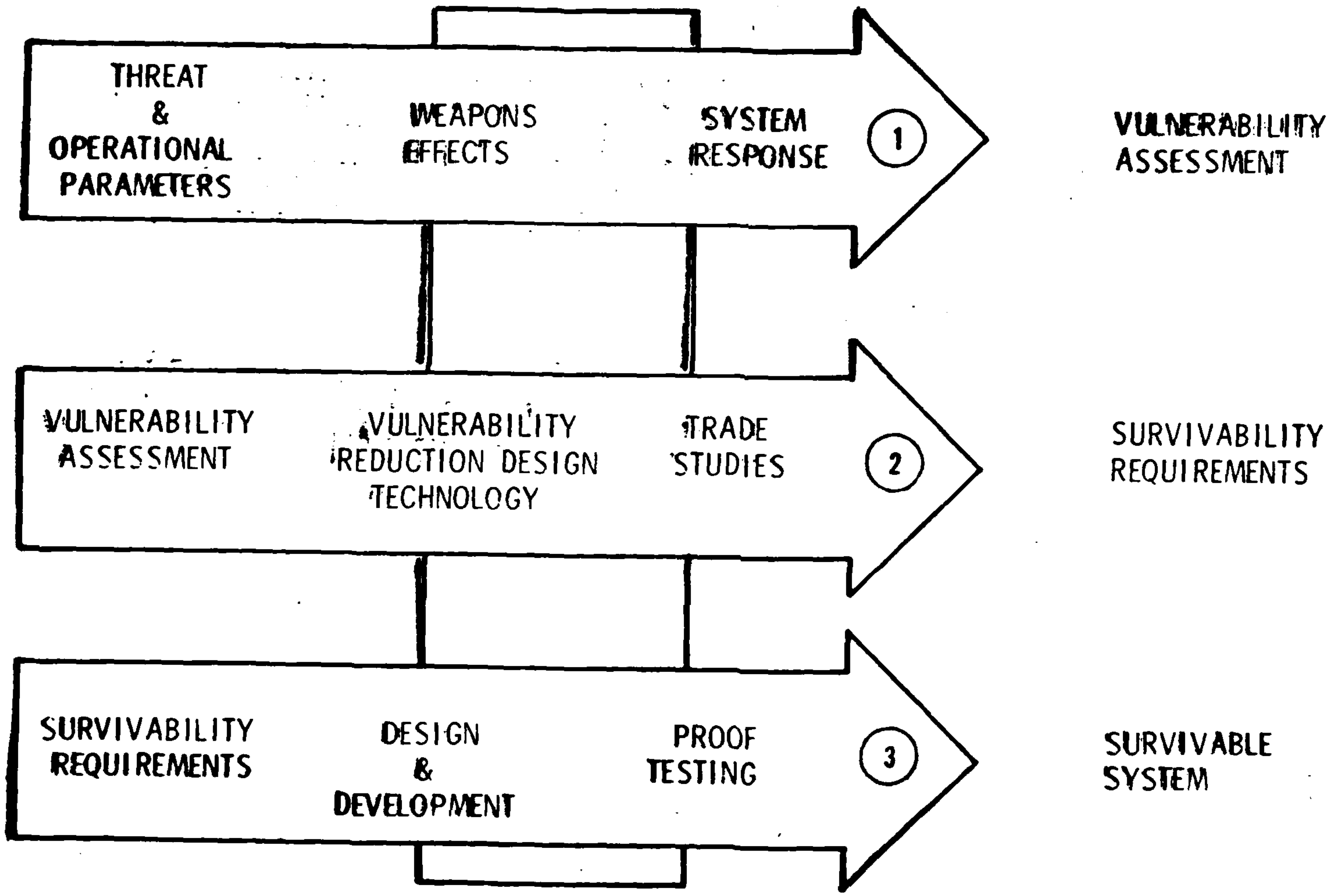
BOOZ-ALLEN APPLIED RESEARCH

AFWAL/FIES/CDIC WRIGHT-PATTERSON AIR FORCE BASE, OH 45433 PH. (513)255-4840/3956, AV. 785-4840/3956

13

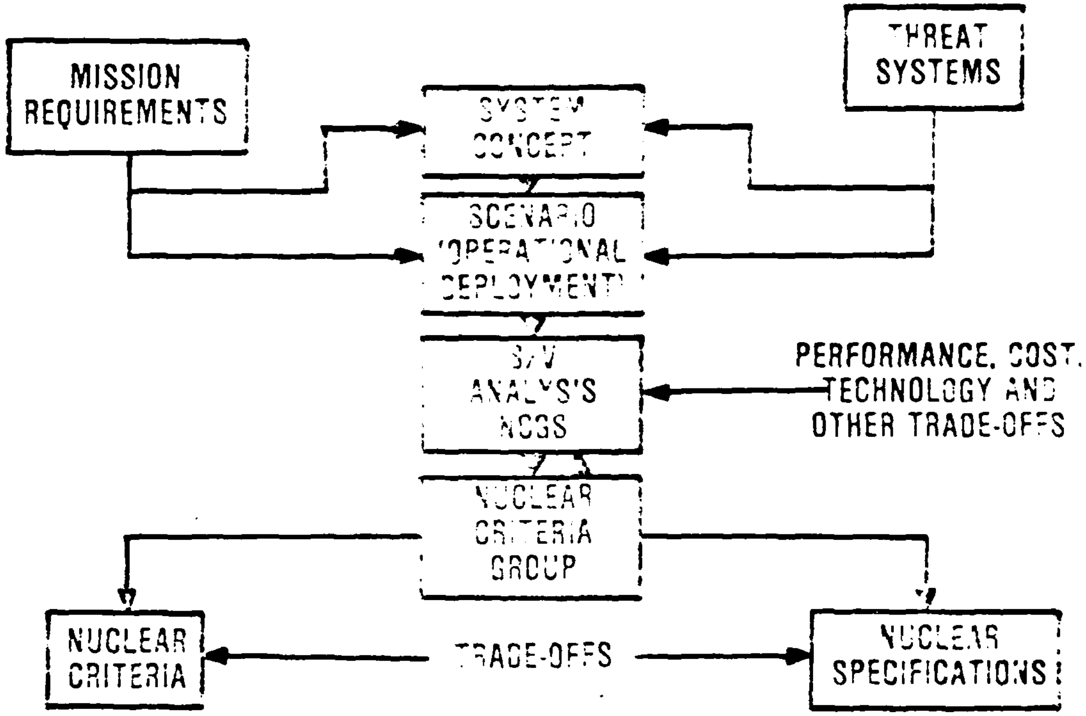
15

ELEMENTS OF ANY S/V PROGRAM



17

TAILORING NUCLEAR SPECIFICATIONS



18

SYSTEM S/V SPECIFICATIONS

CONFIGURATION

- PERFORMANCE
- DETECTABLES
- SURVIVABILITY LEVELS

SUBSYSTEMS

- SPECIFIC ALLOCATIONS
- SUBCONTRACT SPECIFICATIONS
- ASSOCIATE CONTRACTORS AGREEMENTS

AIR SURVIVAL

- FACTORS
  - PREVENT OR DELAY DETECTION
  - AVOID BEING HIT IF DETECTED
  - SURVIVE IF HIT

DETECTION PROBABILITY

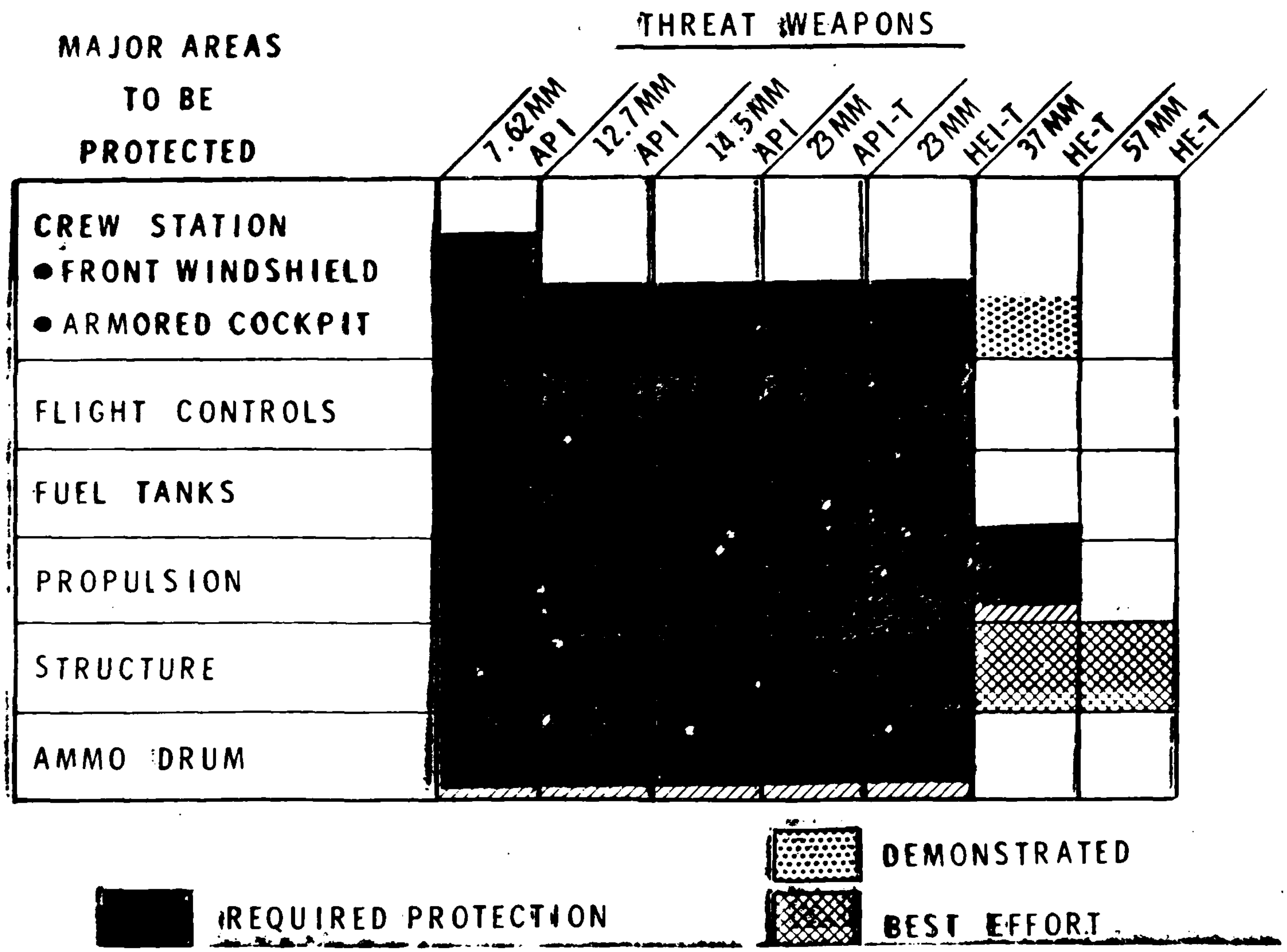
- SIGNATURES
  - AURAL
  - INFRA-RED
  - OPTICAL
  - RADAR
- ECM
- TACTICS
- TERRAIN

- HIT PROBABILITY
  - SPEED
  - MANEUVERABILITY
  - SIZE
  - ECM
  - TACTICS

- KILL PROBABILITY
  - SHIELDING
  - REDUNDANCY
  - SEPARATION
  - CONCENTRATION

20

A-10 ANTI-AIRCRAFT DESIGN REQUIREMENTS



21

ANALYSIS

- VULNERABILITY
  - TARGET DESCRIPTION
  - VULNERABLE AREA CALCULATION
    - SYSTEM/SUBSYSTEM COMPONENT DETAILS
- SURVIVABILITY
  - THREAT SCENARIO
  - THREAT SYSTEM CHARACTERISTICS
  - AIRCRAFT VULNERABILITY
  - PENETRATION AIDS
  - TACTICS

(22)

VULNERABILITY ASSESSMENT

- MANUAL CALCULATIONS
  - DRAWINGS
  - PLANIMETER
  - PENETRATION EQUATIONS/EMPIRICAL DATA
- COMPUTER CODES
  - TARGET DESCRIPTIONS
  - VULNERABLE AREA PROGRAMS
    - FASTGEN
    - COVART

23

PART II

FUTURE SYSTEMS

(24)

USAF SPECIFICATIONS / STANDARDS

(ASD INITIATIVE)

OBJECTIVE: TO DEVELOP PRIMARY SPECS & STDS TAILORABLE TO SYSTEMS WITH REQUIREMENTS STATED IN TERMS OF OPERATIONAL NEEDS AND HANDBOOKS TO PROVIDE TECHNICAL BACK-UP, RATIONALE, AND LESSONS LEARNED.

MILITARY STANDARD

AERONAUTICAL SYSTEMS MISSION COMPLETION IN A COMBAT ENVIRONMENT

AREAS OF CONCERN:

1. AVOIDING DETECTION
2. IF DETECTED, AVOID HIT
3. AVOIDING LOSS OF MISSION
4. AVOIDING LOSS OF CREW & AIRCRAFT AND / OR REDUCING % OF DETECTION, HIT OR LOSS

OPERATIONAL NEEDS ADDRESSED:

- o PRIMARY MISSION
  - — FIRST DAY
  - — SUBSEQUENT DAYS
- o SECONDARY MISSION
  - — FIRST DAY
  - — SUBSEQUENT DAYS
- o THREATS
  - — NONNUCLEAR
  - — NUCLEAR
- o POST--COMBAT AVAILABILITY

27

EXCERPTS:

3.2.1.1 <u>FIRST DAY</u>. ON THE FIRST DAY OF COMBAT THE PRIMARY MISSION OBJECTIVE WILL BE ____________. THE SYSTEM MUST PERFORM THIS MISSION ON ________% OF THE SORTIES FLOWN, AND MUST HAVE ______% OF ALL SORTIES RETURN TO A RECOVERY BASE.

3.4.1 <u>FIRST SORTIE</u>. SYSTEMS RETURNING TO A RECOVERY BASE AFTER THEIR FIRST SORTIE SHALL BE CAPABLE OF FIELD MAINTENANCE SUCH THAT ______% OF THE SYSTEMS ARE CAPABLE OF PERFORMING THE SUBSEQUENT MISSION OF ____________ WITHIN ______ HOURS.

28

EXCERPTS — CONT'D:

3.5.1 <u>IR SIGNATURE</u>. THE SYSTEM SHALL BE DESIGNED TO AVOID DETECTION BY THE FOLLOWING IR SENSORS ________ AT RANGES OF ________ ON ________% OF ITS ENCOUNTERS AT THE FOLLOWING ASPECT ANGLES ________ AND IN THE FOLLOWING ATMOSPHERIC CONDITIONS ______.

3.8.8 <u>ARMOR PIERCING PROJECTILES</u>. THE SYSTEM SHALL BE DESIGNED TO COMPLETE THE ______ MISSION(S) AFTER IMPACT FROM A RANGE OF ____ BY A ____ THREAT IN THE FOLLOWING FLIGHT CONDITIONS ________, AND TO COMPLETE THE _____ MISSION(S) AFTER IMPACT FROM ____ PROJECTILES HAVING A DISTRIBUTION OF ______ FIRED FROM A RANGE OF _____ BY A _____ THREAT IN THE FOLLOWING FLIGHT CONDITION _______. THE SYSTEM SHALL BE ABLE TO FLY _____ AFTER IMPACT FROM THE SINGLE PROJECTILE, AND _____ AFTER IMPACT FROM MULTIPLE PROJECTILES.

EXCERPTS — CONT'D:

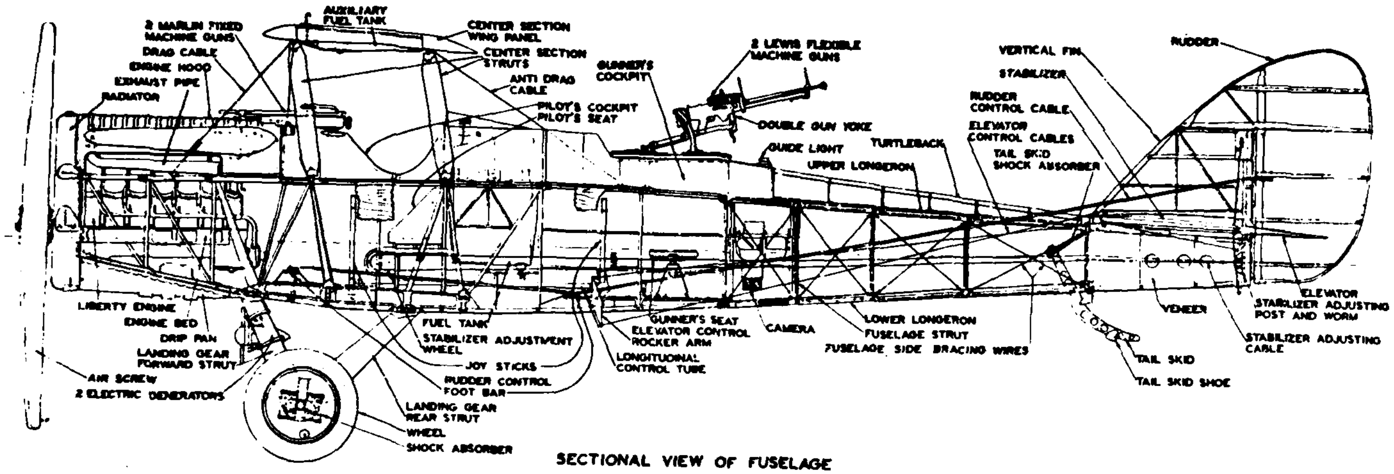
4.5.2.2 TEST (RCS). THE FINAL SYSTEM PRODUCTION DESIGN SHALL BE VALIDATED THROUGH TESTS IN THE __________ FACILITY.

30

CURRENT STATUS

- MILITARY STANDARD -- DRAFT COMPLETED, CURRENTLY IN TECHNICAL COMMITTEE REVIEW.
- HANDBOOK -- IN PREPARATION, APPROXIMATELY 25% COMPLETED. AIMING FOR JUNE 1981 DRAFT.

31



SECTIONAL VIEW OF FUSELAGE

DEHAVILLAND 4 WITH LIBERTY "12"

T.D.B./P.P.-7/18

T.D.B./P.P.-7/18

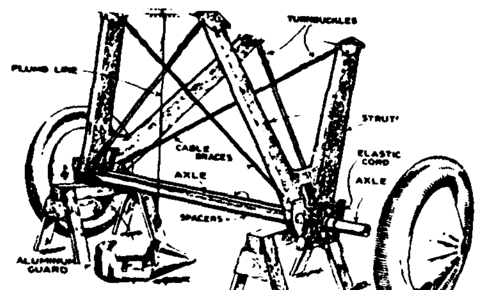
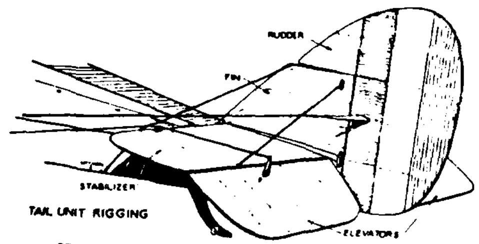


FIG. 6
LANDING GEAR
DE HAVILLAND 4

DeHavilland-4 (Liberty 12)

T.D.B./P.P.-7/18

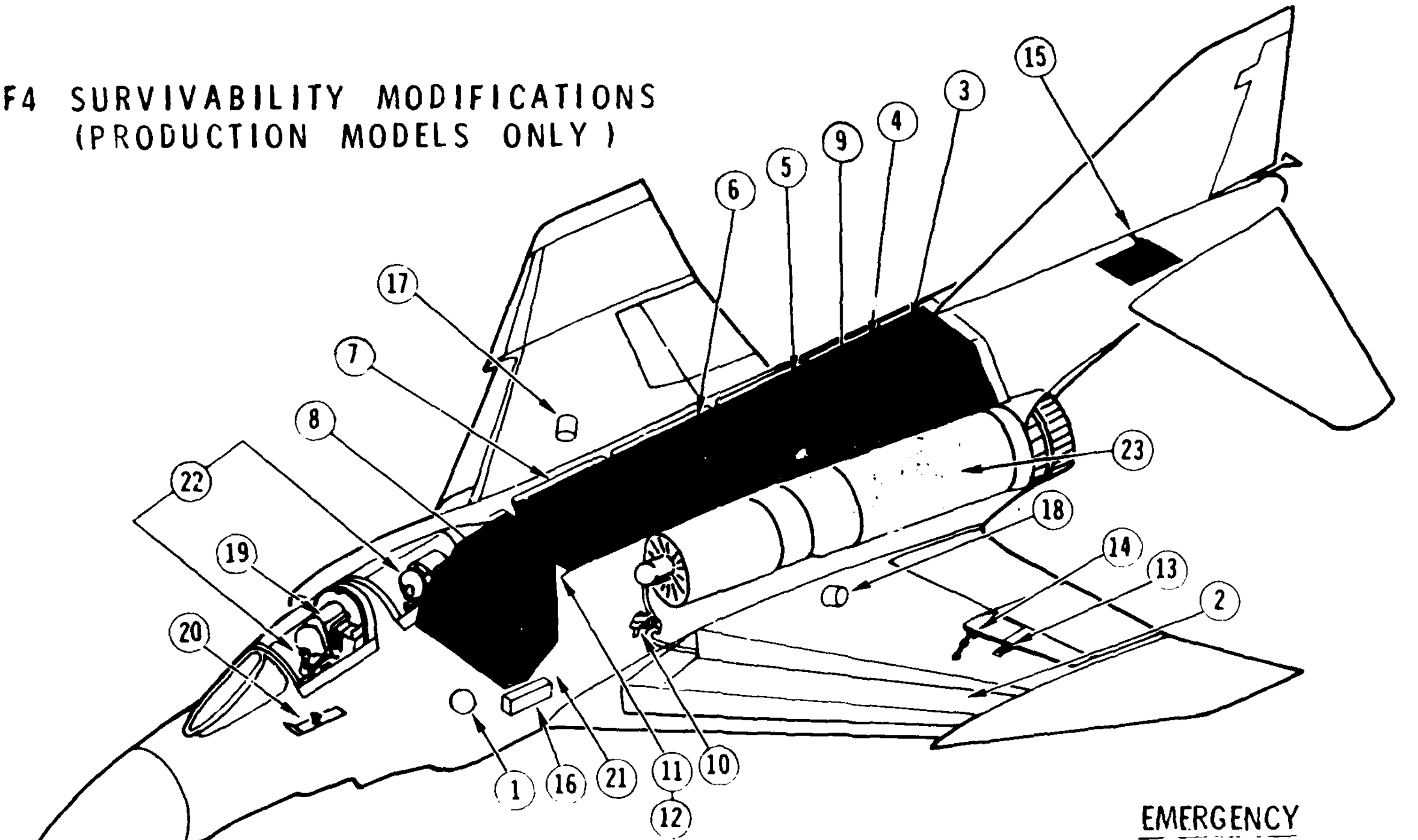


TAIL UNIT RIGGING
DE HAVILLAND 4

FIG 12

32

F4 SURVIVABILITY MODIFICATIONS
(PRODUCTION MODELS ONLY)



KIT TYPE ARMOR PLATE

- OXYGEN AND UTILITY HYDRAULIC BAY DOORS (EXTERNAL ARMOR)

FUEL SYSTEM

- SELF SEALING CELLS
- RETICULATED FOAM
- SELF SEALING LINES AND COMPONENTS
- SEPARATED FUEL FEED SYSTEM

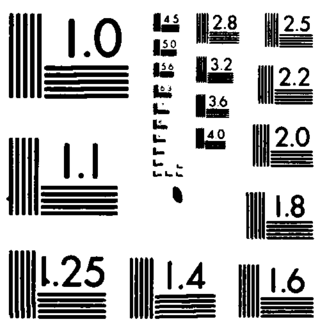
EMERGENCY POWER PACK

- ARMOR PLATED EMERGENCY HYDRAULIC STABILATOR POWER SYSTEM

33

AD-A113 556 JOINT TECHNICAL COORDINATING GROUP ON AIRCRAFT SURVIV--ETC F/G 1/3
PROCEEDINGS, A WORKSHOP IN SURVIVABILITY AND COMPUTER-AIDED DES--ETC(U)
1981
UNCLASSIFIED JTCG/AS-81-D-001 NL

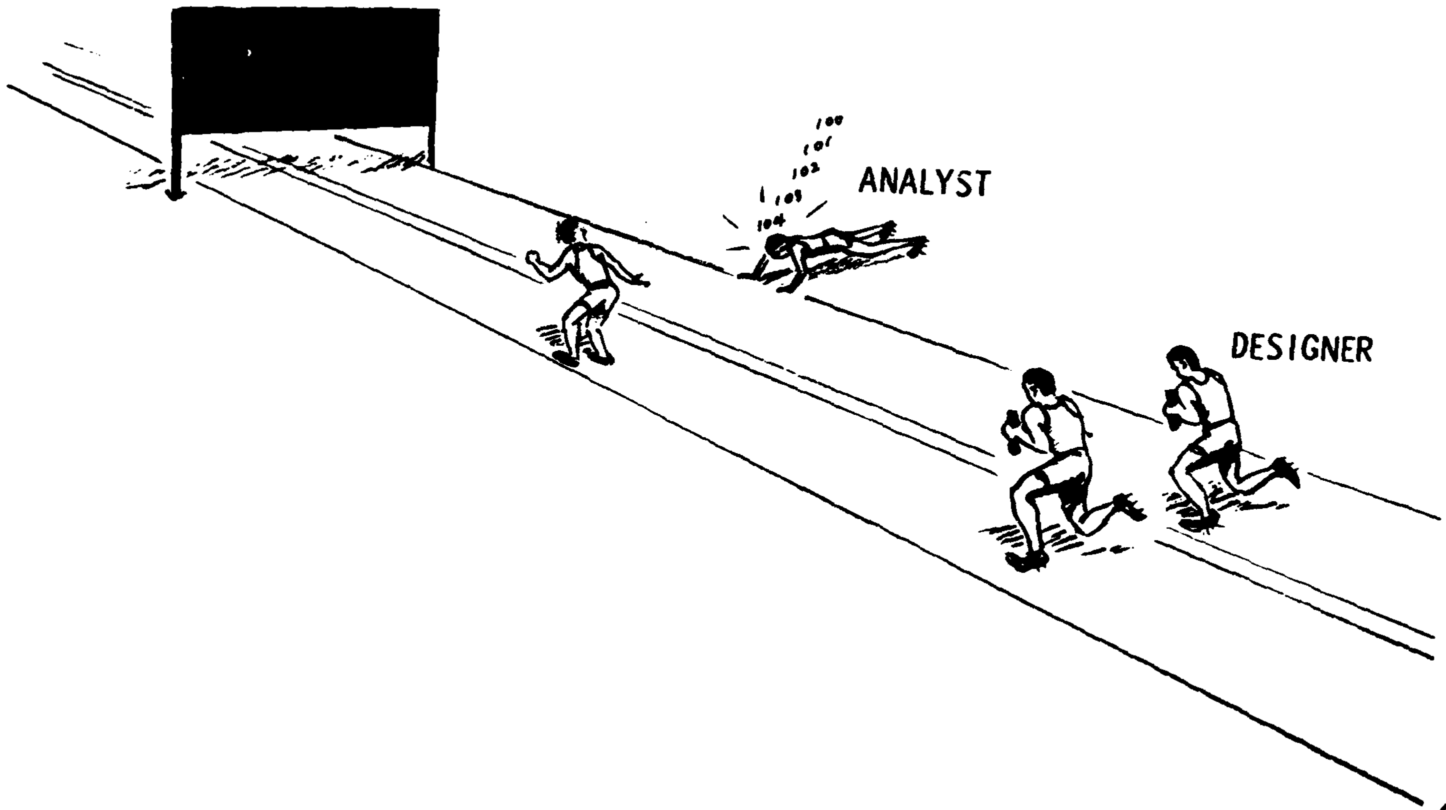
END
DATE
FILMED
5-82
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TEAM EFFORT

FDTS 7-9-18



34

SURVIVABILITY/VULNERABILITY CONSIDERATIONS
IN CONCEPTUAL DESIGN

Joseph A. Arrighi
Deputy Director of Engineering
Fairchild Republic Company
Farmingdale, New York

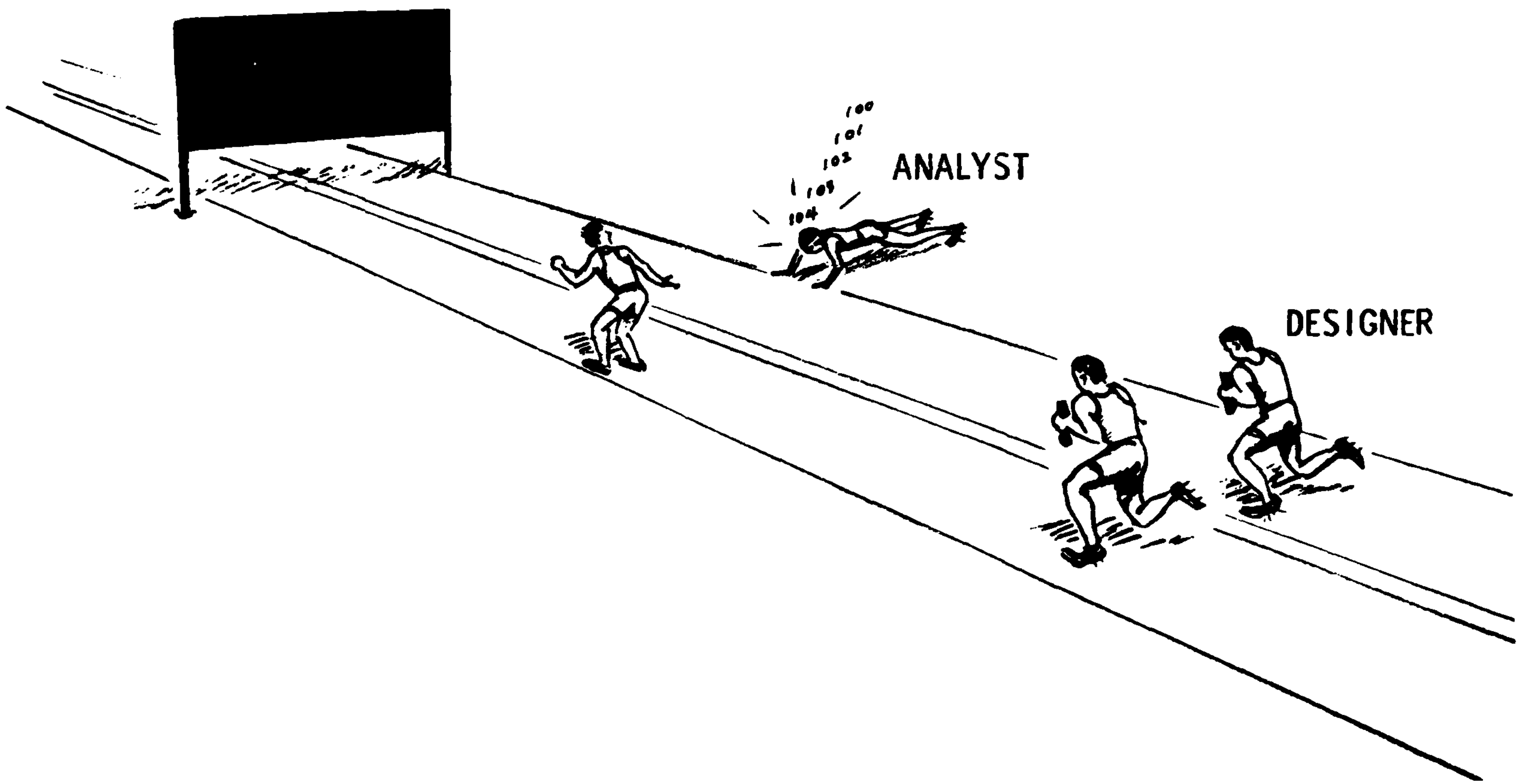
SURVIVABILITY/VULNERABILITY CONSIDERATIONS IN CONCEPTUAL DESIGN

Joseph A. Arrighi
Deputy Director of Engineering
Fairchild Republic Company
Farmingdale, New York

Fairchild Republic has recently completed a USAF/FDL contract, "Survivability Methodology for Aircraft Conceptual Design" (Contract No. F33615-78-C-3426), sponsored by the JTCG/AS. While the scope of the total contract is outlined and some of the methodology and results are illustrated, attention is focused on Task I, and its four subtasks, which is specifically appropriate to this symposium/workshop. The conceptual design process is discussed, and the role which can be played by the S/V analyst is defined. A framework for introducing graphics in general, and CAD in particular, into survivability considerations is thus developed.

TEAM EFFORT

FDTS 7-9-18



S/V IS PART OF CONCEPTUAL DESIGN

AS A RESULT OF A RECENT STUDY CONTRACT PERFORMED BY FRC, AND THE METHODOLOGY DEVELOPED AS A CONSEQUENCE, WE BELIEVE THAT S/V CAN BE MADE AN INTEGRAL PART OF CONCEPTUAL DESIGN OF AIRCRAFT. THE CONTRACT PERFORMED WAS WITH THE S/V BRANCH OF THE FLIGHT DYNAMICS LABORATORY AND WAS SPONSORED BY THE JTCG/AS.

I WILL DESCRIBE THE TASKS INVOLVED, TELL YOU OF THE CONTENT OF TASK I, AND, BECAUSE IT IS SO PERTINENT TO THIS WORKSHOP, SPEND MOST OF MY TIME IN THAT TASK. BUT, I'LL ALSO BRIEFLY ILLUSTRATE THE METHODOLOGY WHICH WAS DEVELOPED AND SHOW YOU SOME OF THE VALIDATION OF THE METHODOLOGY. I'LL ALSO DRAW CONCLUSIONS.

WHAT WAS INVOLVED IN THE STUDY?

S/V IS PART OF CONCEPTUAL DESIGN

- FDL/FRC CONTRACT (JTCG/AS)
- 3 TASKS
- TASK I
- METHODOLOGY ILLUSTRATED
- DEMONSTRATED — A-10A, OV-10A
- RESULTS

COMPLETED 3 TASKS

THERE WERE THREE TASKS INVOLVED. THE FIRST REQUIRED AN INVESTIGATION OF CURRENT PRACTICES BE MADE. THE SECOND DEFINED A METHODOLOGY TO BE DEVELOPED, AND, THE THIRD REQUIRED ANALYSES OF SAMPLE CASES, USING THE METHODOLOGY, FOR VALIDATION AND/OR REVISION PURPOSES.

TASK I WAS THE SET UP TASK. IT'S UNDERLYING PURPOSE WAS TO -----

COMPLETED 3 TASKS

I. INVESTIGATE

II. DEVELOP METHODOLGY

III. PERFORM SAMPLE CASES

FIT S/V ANALYST INTO CONCEPTUAL DESIGN PROCESS

----- DETERMINE HOW THE S/V ANALYST COULD BE FIT INTO THE CONCEPTUAL DESIGN PROCESS SO THAT S/V WOULD BECOME AN INTEGRAL PART.

TASK I CALLED FOR INVESTIGATING AND IDENTIFYING THE SO-CALLED "CONTRIBUTORS" TO A/C SURVIVABILITY, TO SET FORTH WHAT ARE THE CURRENT APPROACHES TO ASSESSING, ENHANCING AND TRADING-OFF SURVIVABILITY, WHAT ARE THE CURRENT CONCEPTUAL DESIGN PRACTICES IN THE FIRST PLACE, AND WHAT ARE THE PROBLEMS AND DEFICIENCIES INVOLVED IN ALL OF THIS. THESE ARE FOUR SUB-TASKS TO TASK I AND I'LL DWELL ON EACH IN TURN.

FROM THE OUTSET, IT WAS NECESSARY TO DEFINE WHAT IS MEANT BY SURVIVABILITY CONTRIBUTORS.

FIT S/V ANALYST INTO CONCEPTUAL DESIGN PROCESS

- INVESTIGATE/IDENTIFY CONTRIBUTORS
- CURRENT APPROACHES
  ASSESS/ENHANCE/TRADE-OFF
- CONCEPTUAL DESIGN PRACTICES
- PROBLEMS AND DEFICIENCIES

SURVIVABILITY CONTRIBUTORS DEFINED

IN THE STUDY, SURVIVABILITY CONTRIBUTORS HAVE BEEN DEFINED AS THOSE DESIGN CHARACTERISTICS WHICH ARE NORMALLY INCORPORATED IN THE DESIGN OF AN AIRPLANE AND WHICH CAN BE REARRANGED, IMPROVED UPON OR OTHERWISE ADJUSTED TO ACHIEVE MAXIMUM BENEFIT TO SURVIVABILITY. IN OTHER WORDS. CONTRIBUTORS ARE ALREADY THERE AND ARE NOT ADDED JUST BECAUSE OF SURVIVABILITY.

IN GENERAL. THERE ARE TWO CATEGORIES OF CONTRIBUTORS. --------

SURVIVABILITY CONTRIBUTORS DEFINED

"- - - - <u>DESIGN CHARACTERISTICS NORMALLY</u>
<u>INCORPORATED</u> - - - WHICH CAN BE RE-ARRANGED,
IMPROVED UPON OR - - - ADJUSTED TO ACHIEVE
MAXIMUM BENEFIT TO SURVIVABILITY."

THERE ARE 2 CATEGORIES OF CONTRIBUTORS

---------- THOSE WHICH ARE CONFIGURATION SENSITIVE AND THOSE WHICH ARE PERFORMANCE SENSITIVE. THE FIRST ARE GEOMETRY AND HARDWARE RELATED AND THE SECOND ARE AGILITY RELATED.

THESE ARE SPECIFICALLY INTER-RELATED IN CURRENT CONCEPTUAL DESIGN PRACTICES.

THERE ARE 2 CATEGORIES OF CONTRIBUTORS

CONFIGURATION SENSITIVE

CONTRIBUTIONS: VULNERABLE AREA GEOMETRY, HARDWARE RELATED

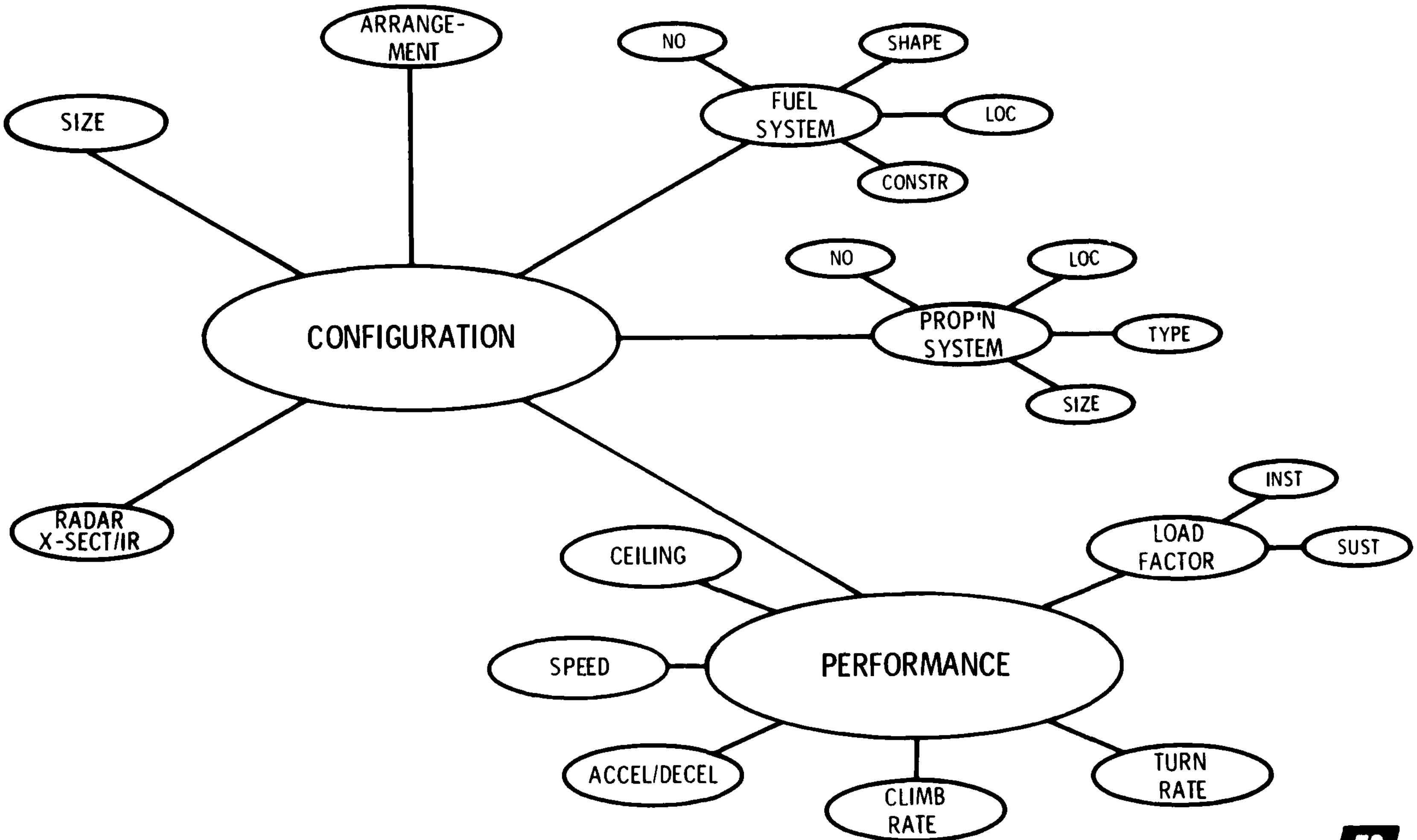
PERFORMANCE SENSITIVE

CONTRIBUTIONS: AGILITY IN END GAME

CONTRIBUTORS ARE INTER-RELATED

SHOWN GRAPHICALLY ARE SOME OF THE CONTRIBUTORS OF BOTH TYPES. AIRCRAFT SIZE, ARRANGEMENT, THE NUMBER, SHAPE AND LOCATION OF FUEL CELLS, THE TYPE AND SIZE OF ENGINES ARE ALL CONFIGURATION SENSITIVE SURVIVABILITY CONTRIBUTORS. SPEED AT VARIOUS ALTITUDES, CLIMB RATE AND THE ABILITY TO IMPOSE INSTANTANEOUS AND SUSTAINED LOAD FACTORS ARE PERFORMANCE SENSITIVE CONTRIBUTORS, MANY OF WHICH ARE DEPENDENT ON SPECIFIC EXCESS POWER AVAILABLE. THE INTER-LINK BETWEEN THEM, REPRESENTED BY THE DIAGONAL BAR ( ) IS THE CONCEPTUAL DESIGN PROCESS ITSELF.

CONTRIBUTORS ARE INTER-RELATED



CONTRIBUTORS PLAY THESE ROLES

IF WE TRY TO UNDERSTAND THE ROLE PLAYED BY THE VARIOUS CONTRIBUTORS THEN THE RESULT WILL LOOK LIKE WHAT IS DISPLAYED IN THIS TABLE. IN GENERAL, THE CONFIGURATION SENSITIVE CONTRIBUTORS, EXCEPT FOR THE OBSERVABLES, HAVE THEIR GREATEST INFLUENCE ON THE VULNERABILITY OF THE AIRPLANE WHILE THE PERFORMANCE SENSITIVE CONTRIBUTORS HAVE A LARGE INFLUENCE ON SURVIVABILITY IN THE "END GAME" ANALYSES.

SO MUCH FOR THE SURVIVABILITY CONTRIBUTORS. HOW IS SURVIVABILITY ASSESSED?

CONTRIBUTORS PLAY THESE ROLES

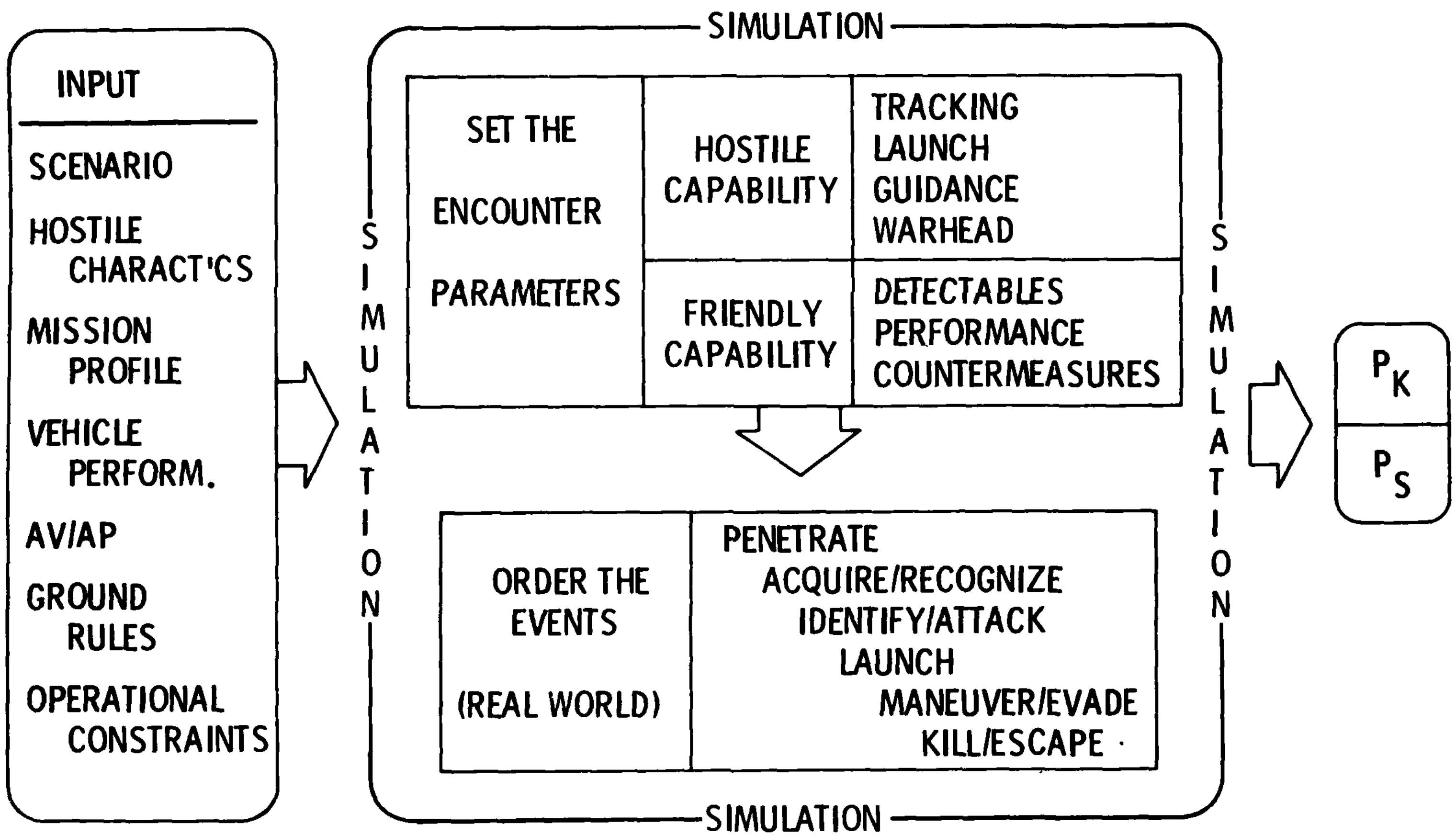
CONTRIBUTOR	ROLE	
	V	S
CONFIGURATION		
SIZE	√	√
ARRANGEMENT	√	
FUEL SYSTEM	√	
PROPULSION SYS.	√	
ARMAMENT	√	
OBSERVABLES		√
PERFORMANCE		√

ASSESSMENT APPROACH IS WELL ESTABLISHED

THE ASSESSMENT APPROACH IS WELL ESTABLISHED IN THE AIRCRAFT DESIGN COMMUNITY. BOTH HOSTILE AND FRIENDLY ENCOUNTER PARAMETERS ARE DETERMINED AND THE REAL WORLD EVENTS ARE ORDERED. THESE ARE SIMULATED IN END GAME MODELS WHICH ARE EXERCISED IN MULTIPLE COMPUTER RUNS. INPUT TO THESE COMPUTER MODELS, IN THE FORM OF GROUND AND AIR SCENARIOS, THE CHARACTERISTICS OF HOSTILE AND FRIENDLY WEAPONS, AND OTHER INFORMATION AND DATA, ARE MADE. AND, EITHER THE KILL OR THE SURVIVAL PROBABILITIES, AS FUNCTIONS OF INPUT VARIABLES, RESULT.

HOWEVER - - - - - -

ASSESSMENT APPROACH IS WELL ESTABLISHED



ASSESSMENT ACCURACY IS QUESTIONABLE

--------- THE ACCURACY OF RESULTS IS QUESTIONABLE. THE MODELS THEMSELVES CANNOT TRULY REPRESENT ALL REAL WORLD EVENTS AND THE HEAVY DEPENDENCE ON DEFAULT VALUES INSTEAD OF MORE DEFINITE INPUTS BOTH CONTRIBUTE TO INACCURACY. IT IS COMMON PRACTICE TO DISBELIEVE THE ABSOLUTE VALUE OF THE RESULTS AND TO CONSTRAIN THEIR INTERPRETATION TO COMPARISONS OF LIKE VEHICLES EXERCISED IN SIMILAR SITUATIONS.

AND NOW, WHAT IS THE CURRENT APPROACH TO SURVIVABILITY ENHANCEMENT - BEFORE THAT THOUGH, ---------

ASSESSMENT ACCURACY IS QUESTIONABLE

- DEFAULT

  vs

  DEFINITIVE

- COMPARATIVE

ENHANCEMENT IS DEFINED

--------- WE MUST DEFINE WHAT IS MEANT BY "ENHANCEMENT". AS DISTINCT FROM SURVIVABILITY CONTRIBUTORS, SURVIVABILITY ENHANCEMENT IS DEFINED AS ANY ADDITION OR MODIFICATION TO A BASELINE AIRCRAFT, NOT NORMALLY CONSIDERED IN CONCEPTUAL DESIGN, FOR THE SOLE PURPOSE OF IMPROVING ITS SURVIVABILITY CHARACTERISTICS. IN GENERAL, ENHANCEMENTS "HARDEN" THE AIRCRAFT AGAINST ATTACK.

THE BASIC DESIGN APPROACH, -------

ENHANCEMENT IS DEFINED

- ADDITION/MODIFICATION
- NOT NORMALLY CONSIDERED
- IMPROVE SURVIVABILITY CHARACTERISTICS

"HARDEN"

ENHANCEMENT APPROACH NOT WELL INTEGRATED

------- WHICH IS NOT WELL INTEGRATED WITH THE CONCEPTUAL DESIGN PROCESS, IS TO COUNTER A THREAT'S FUNCTIONAL ELEMENTS. THESE ELEMENTS ARE THE THREAT'S ABILITY TO DETECT, LOCATE, TRACK, AIM AND CONTROL, AND IT'S TERMINAL EFFECTS.

THESE CAN BE COUNTERED BY EITHER PASSIVE OR ACTIVE MEANS. LISTED IN THE VU-GRAPH ARE THE USUAL MEANS EMPLOYED.

THE LAST OF THE TRIO OF CURRENT APPROACHES STUDIED IS SURVIVABILITY TRADE-OFFS.

ENHANCEMENT APPROACH NOT WELL INTEGRATED

- BASIC APPROACH:
  - COUNTER FUNCTIONAL ELEMENTS
- PASSIVE OR ACTIVE?
- COMMON PRACTICE:
  - DETECTION/LOCATION — — — — ACTIVE
  - TRACK/AIM/FIRE CONTROL — — — ACTIVE
  - TERMINAL EFFECTS — — — — PASSIVE

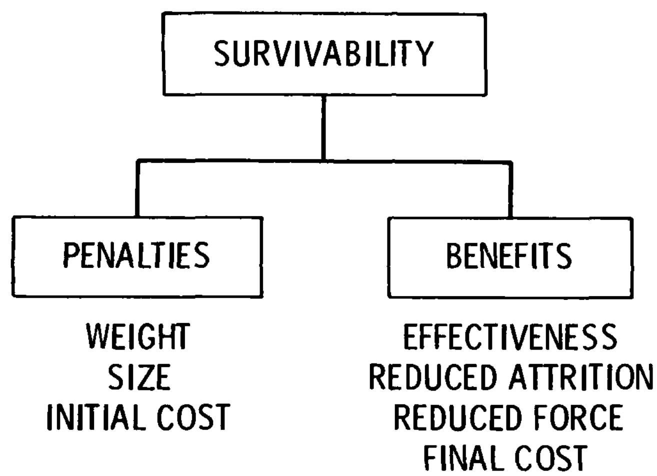
TRADE-OFFS NOT ALL INCLUSIVE

SUCH TRADES IN CONCEPTUAL DESIGN ARE NOT ALL INCLUSIVE. THE GENERAL APPROACH IS TO STUDY VARIOUS QUALITIES, RELIABILITY, MAINTAINABILITY, ETC., OF WHICH SURVIVABILITY IS ONE, TO BALANCE PENALTIES AGAINST BENEFITS, AND TO CHOOSE THE MORE DESIRABLE CHARACTERISTICS BASED ON THE DEFINED DATA. WEIGHT, SIZE AND INITIAL COST PENALTIES CAN PRODUCE BENEFITS LIKE INCREASED EFFECTIVENESS, REDUCED ATTRITION, SMALLER FORCE AND REDUCED LIFE CYCLE COSTS.

COMMON PRACTICE DOES INCLUDE THE PERFORMANCE SENSITIVE SURVIVABILITY CONTRIBUTORS AS PART OF THE CONCEPTUAL DESIGN PROCESS BUT FAILS TO MAKE ADEQUATE PROVISION FOR SURVIVABILITY ENHANCEMENT FEATURES AND FOR VULNERABILITY ASSESSMENT REQUIREMENTS AND THE IMPORTANT INTER-RELATIONSHIP BETWEEN THEM. THIS IS TRUE BECAUSE OF FUNDAMENTAL LIMITATIONS ON REQUIRED DATA.

TRADE-OFFS NOT ALL INCLUSIVE

IN GENERAL



SPECIFICALLY

SURVIVABILITY CONTRIBUTORS	√	[PERFORMANCE SENSITIVE]
SURVIVABILITY ENHANCEMENT	✗	
VULNERABILITY ASSESSMENT	✗	

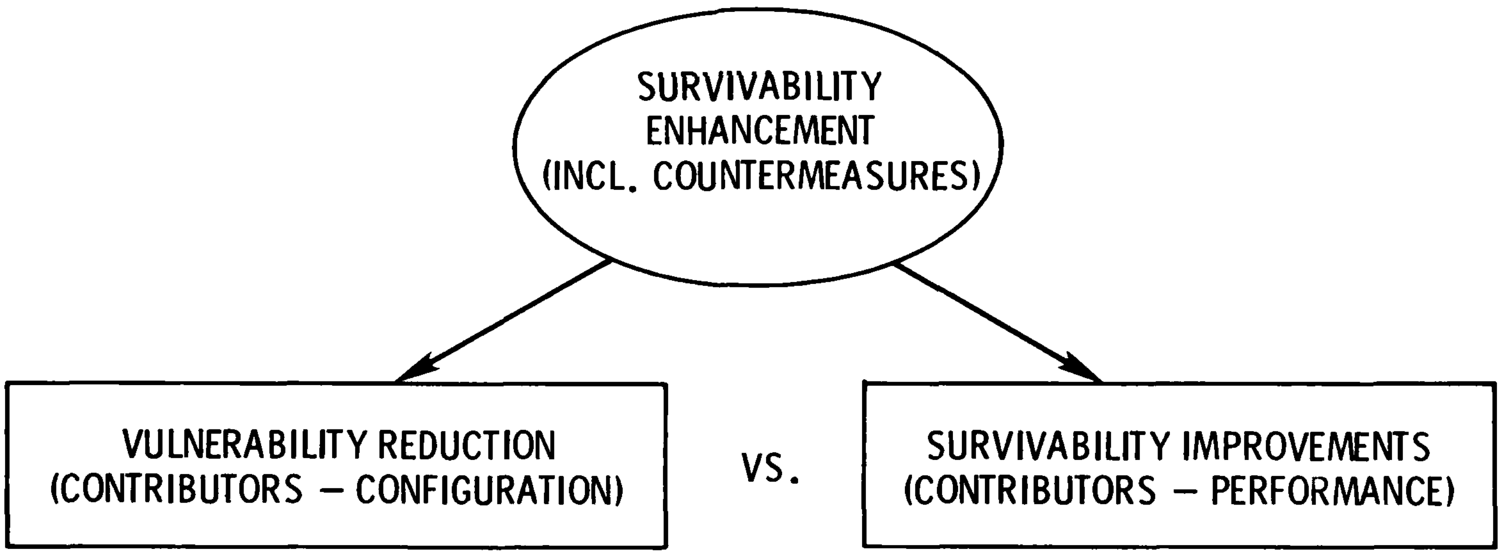
DATA LIMITED

<u>BALANCED TRADE-OFF APPROACH REQUIRED</u>

A **BALANCED TRADE-OFF** CAPABILITY IS REQUIRED IN WHICH VULNERABILITY REDUCTIONS CAN BE BALANCED AGAINST SURVIVABILITY IMPROVEMENTS WITH AND WITHOUT SURVIVABILITY ENHANCEMENT FEATURES. THE CONCEPTUAL DESIGN PROCESS IS FUNDAMENTALLY WELL ARRANGED TO SUPPLY THIS CAPABILITY. IT LACKS ONLY THE METHODOLOGY FOR EMBRACING SURVIVABILITY ENHANCEMENT AND VULNERABILITY REDUCTION.

BUT, BEFORE WE GET INTO THIS, LET'S DEFINE TERMS LIKE CONCEPTUAL, CONCEPTUAL DESIGN, AND CONCEPT FORMULATION.

BALANCED TRADE-OFF APPROACH REQUIRED

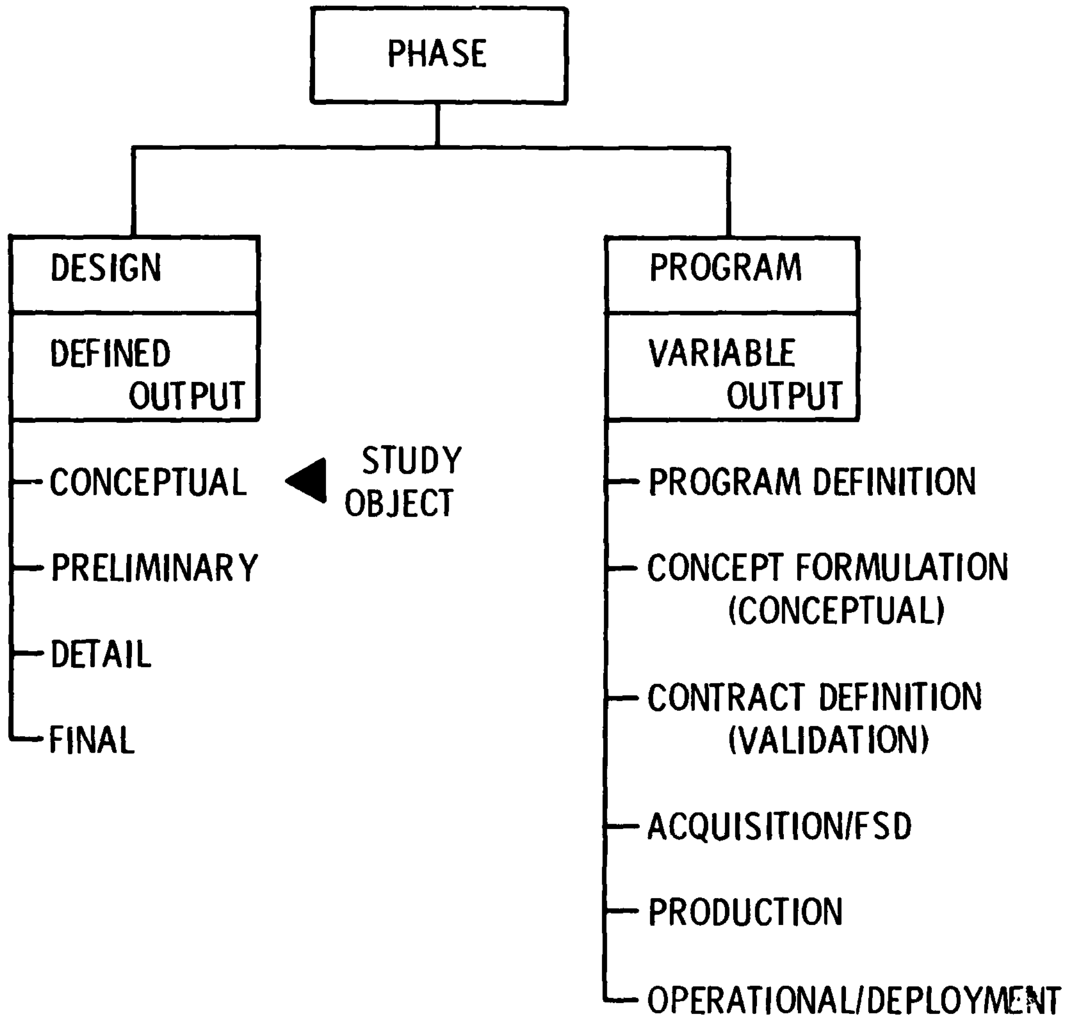


"CONCEPTUAL" IS RELATED TO A DESIGN PHASE

SHOWN ON THIS VU-GRAPH ARE TWO DISTINCTLY DIFFERENT PHASING SCHEMES, ONE IS DESIGN ORIENTED IN WHICH THE OUTPUT IS WELL DEFINED, AND THE OTHER IS PROGRAM ORIENTED IN WHICH THE OUTPUT CAN BE VARIABLE. THE CONTRACTED STUDY WAS PERFORMED IN THE DESIGN ORIENTATION IN WHICH "CONCEPTUAL DESIGN" IS THE FIRST OF A SEQUENCE OF INCREASING DESIGN DEFINITIONS AND LEVELS OF DETAIL.

"CONCEPTUAL DESIGN" IS DEFINED AS ---------------

"CONCEPTUAL" IS RELATED TO A DESIGN PHASE



"CONCEPTUAL DESIGN" IS DEFINED

------- A SYSTEMIZED WORK PROCESS WHICH CONVERTS A SET OR SETS OF REQUIREMENTS INTO ONE OR MORE FEASIBLE DESIGN CONFIGURATIONS SIZED TO MEET THE REQUIREMENTS AND OPTIMIZED FOR END USE BY VARIOUS TRADE STUDIES. IT MAY INCLUDE TRADING ONE CONFIGURATION AGAINST ANOTHER - USUALLY CALLED POINT DESIGNS. IT IS THE EARLIEST DESIGN RESPONSE TO SPECIFIC REQUIREMENTS. ITS ORIENTATION IS BASICALLY TOWARDS VEHICLE DESIGN.

ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH TO THE CONCEPTUAL DESIGN PROCESS.

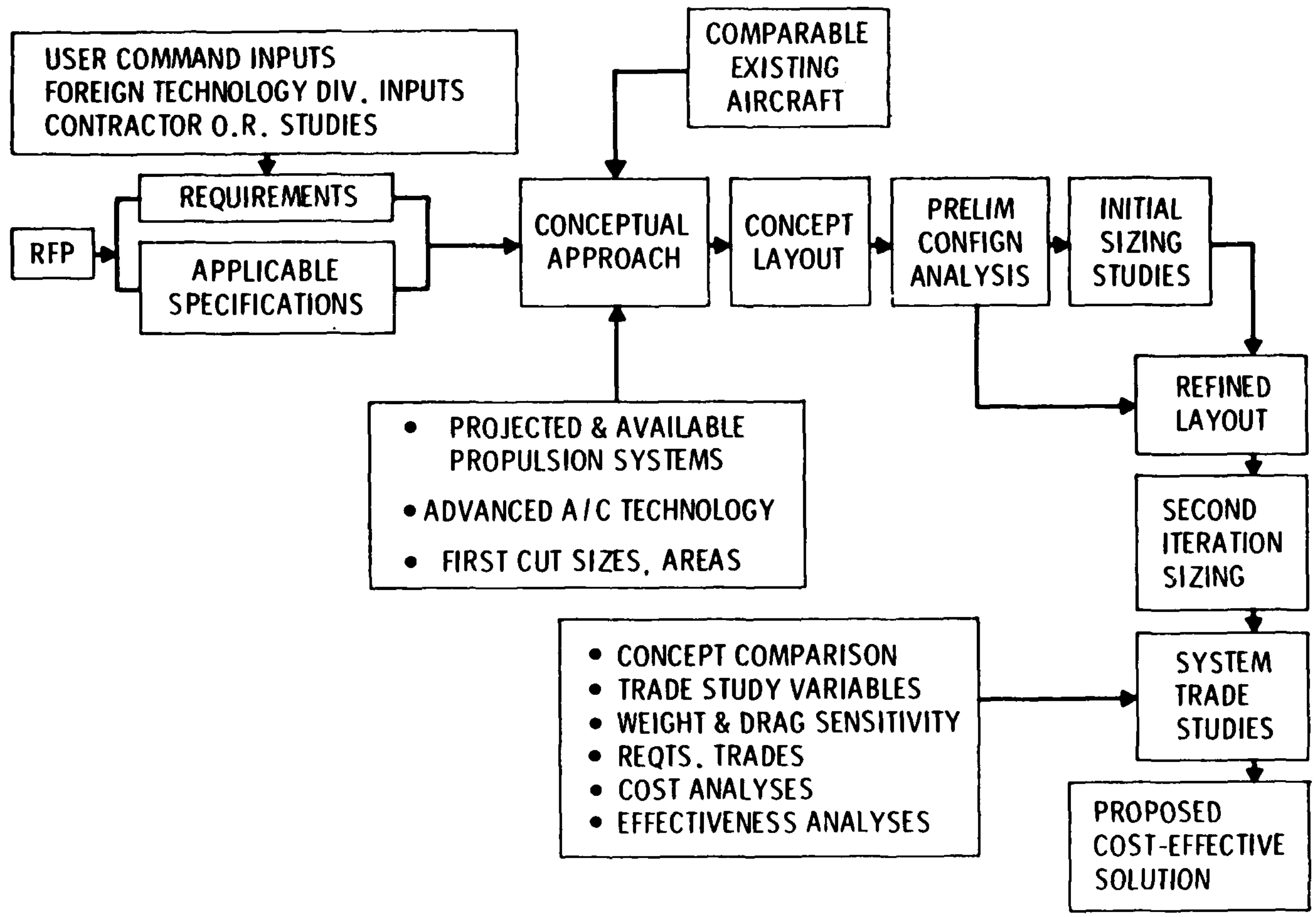
"CONCEPTUAL DESIGN" IS DEFINED

- SYSTEMIZED WORK PROCESS
- REQUIREMENTS → FEASIBLE CONFIGURATION
- SIZED
- OPTIMIZED BY TRADES (POINT DESIGNS)
- EARLIEST RESPONSE TO SPECIFIC REQUIREMENTS
- PARAMETRIC
- BASIC ORIENTATION → VEHICLE DESIGN

ALL A/C DESIGNERS USE A SIMILAR APPROACH

AT FRC, DATA FROM VARIOUS SOURCES ARE ASSEMBLED TO DEVELOP ONE OR MORE CONCEPTUAL APPROACHES FOR WHICH CONCEPT LAYOUTS OR ARRANGEMENT DRAWINGS ARE MADE. AFTER PERFORMING CERTAIN ANALYSES FOR DEVELOPING INPUT DATA, A COMPREHENSIVE AIRCRAFT SIZING AND TRADE-STUDY PROGRAM IS EXERCISED TO ELIMINATE UNLIKELY SOLUTIONS AND TO SELECT LIKELY CANDIDATES FOR ITERATION AND REFINEMENT. SYSTEM LEVEL TRADE STUDIES ARE PERFORMED ON ALL VIABLE CANDIDATES TO PROPOSE THE MOST COST EFFECTIVE RESPONSE TO THE REQUIREMENTS.

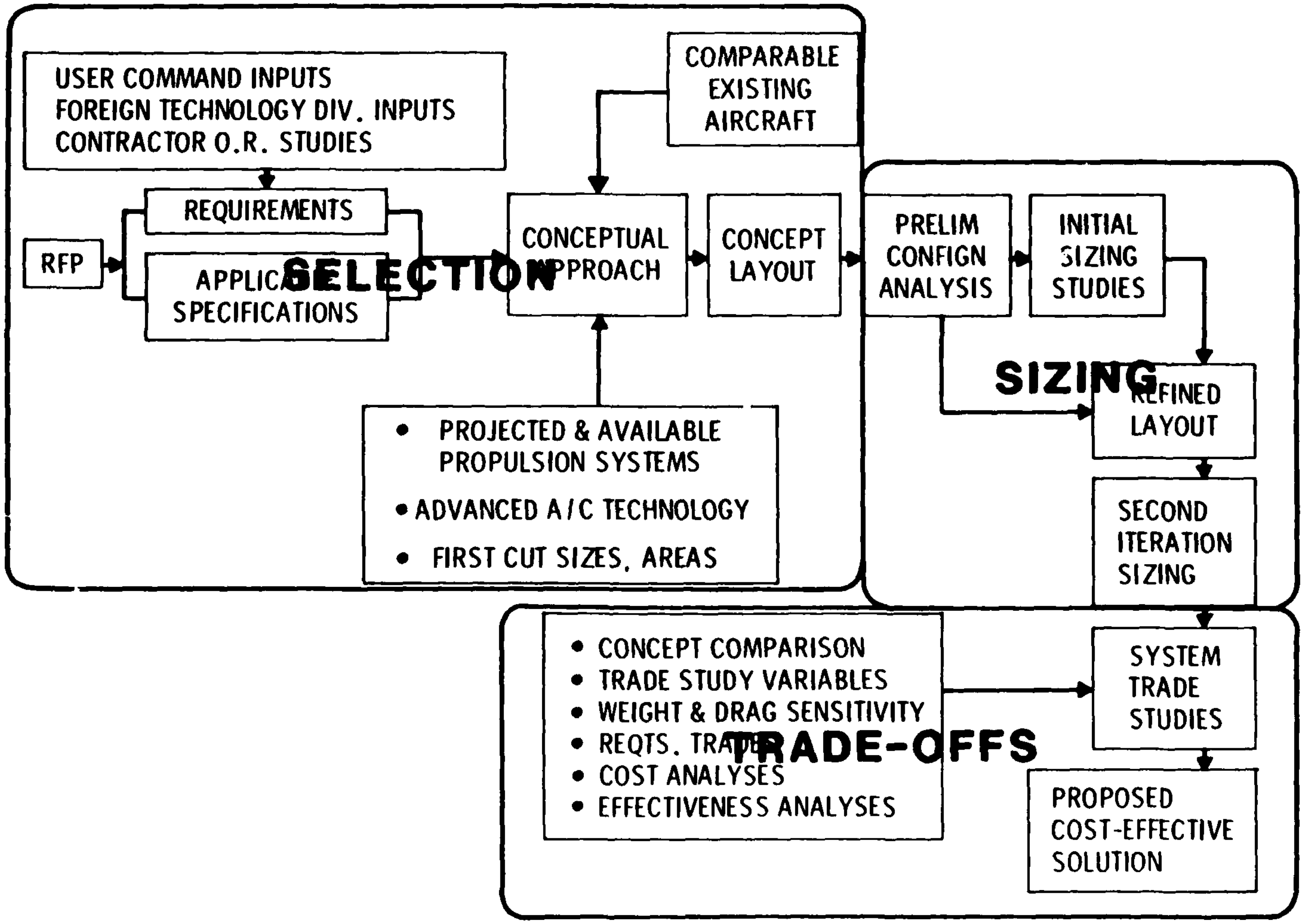
ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH



OVERLAY

THE PROCESS PREVIOUSLY SHOWN IS ROUGHLY DESCRIBED IN THREE GENERALIZED PROCESS STEPS: SELECTION, SIZING AND TRADE STUDY.

ALL AIRCRAFT DESIGNERS USE A SIMILAR APPROACH

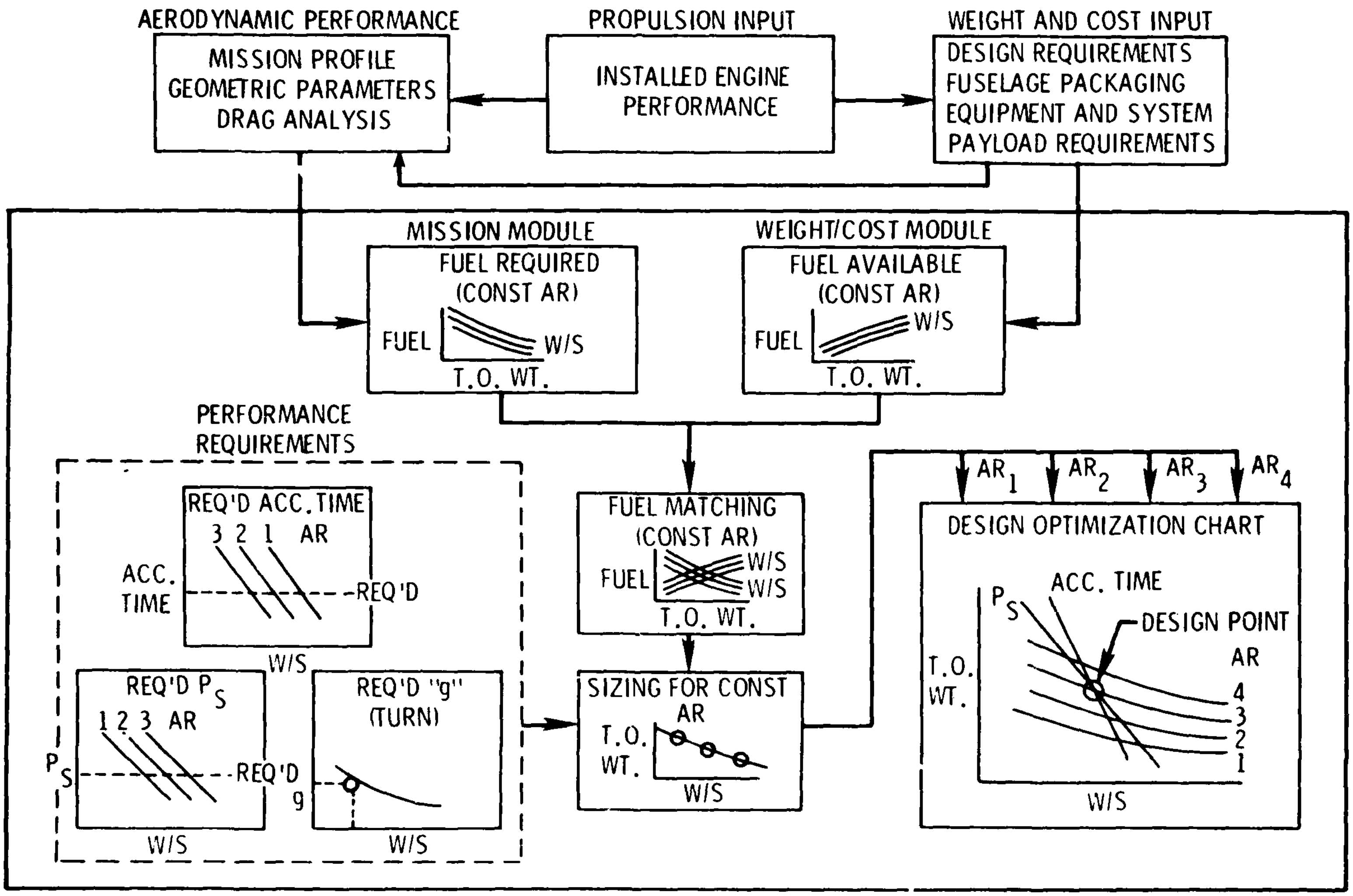


FRC PROCESS IS PARAMETRIC & COMPUTERIZED

FRC'S A/C SIZING AND TRADE-STUDY PROCESS IS HEAVILY COMPUTERIZED AND OPERATES TO EXAMINE A WIDE RANGE OF PARAMETERS. IT IS DEPENDENT ON THREE SUB-MODULES FOR SETTING AERODYNAMIC, PROPULSION AND WEIGHT/COST PARAMETERS, AND SIZES AIRCRAFT BY OVERLAPPING MISSION FUEL REQUIREMENTS FROM A MISSION MODULE WITH FUEL AVAILABLE CALCULATIONS FROM THE WEIGHT-COST MODULE. THE MATCH POINTS ON FUEL SET THE AIRCRAFT SIZES. THE PARAMETRIC SIZING INFLUENCES OF FACTORS SUCH AS ASPECT RATIO, HERE SHOWN AS AR, WING LOADING SHOWN AS WS, AND OTHERS, CAN BE DETERMINED. SUBSIDIARY CALCULATIONS TO SET MINIMUM (OR MAXIMUM) REQUIREMENTS FOR THESE PARAMETERS ARE INCLUDED. THE END RESULT IS AN OPTIMIZED POINT DESIGN CAPABLE OF SATISFYING ALL REQUIREMENTS.

THE NEXT VU-GRAPH SHOWS THIS FUEL MATCHING/AIRCRAFT SIZING RELATIONSHIP IN MORE DETAIL -----------

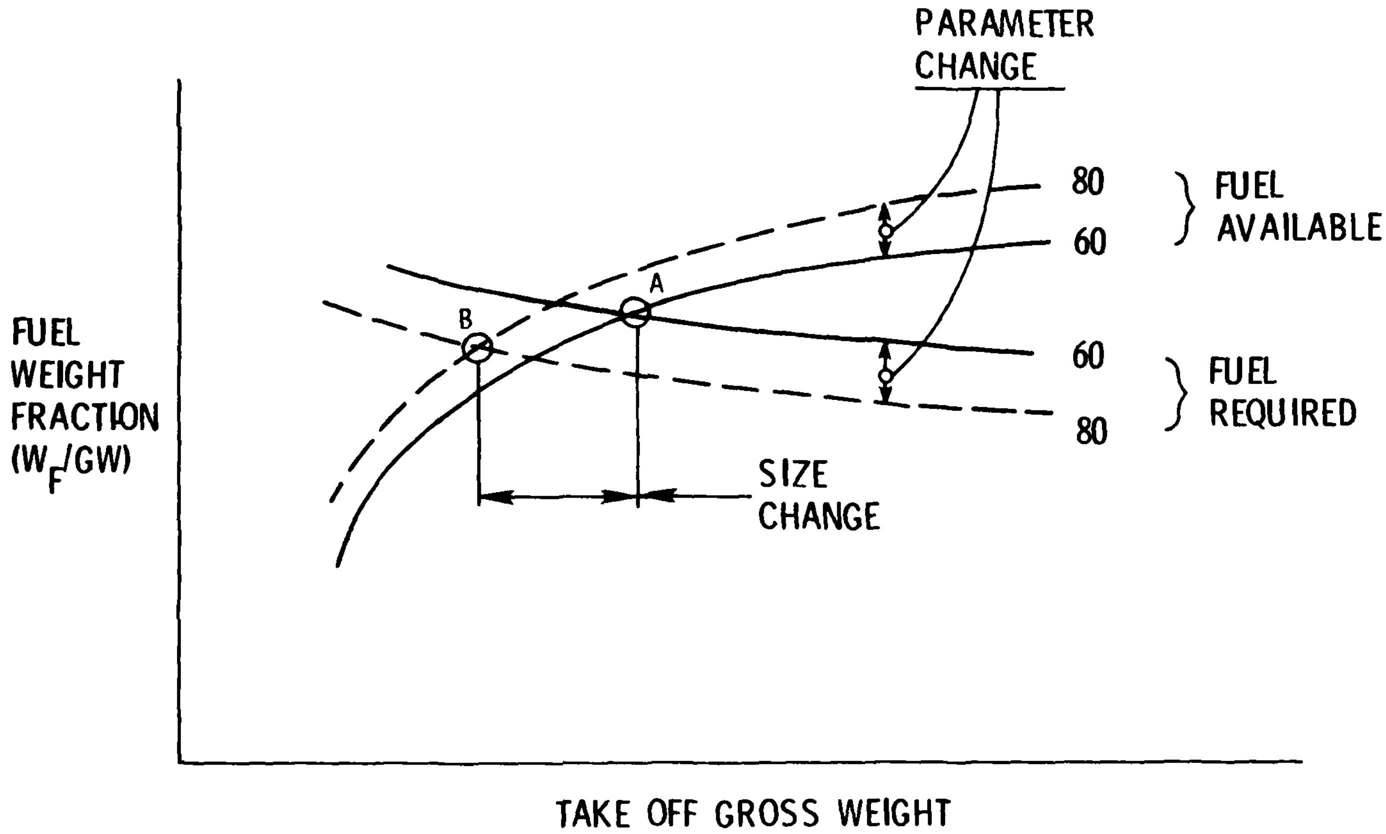
FRC PROCESS IS PARAMETRIC & COMPUTERIZED



FRC SIZING PROCESS IS USED FOR TRADE-OFFS

---- AND ALSO SHOWS HOW AIRCRAFT SIZE IS INFLUENCED IN THE TRADE STUDIES. A WING LOADING TRADE STUDY IS ILLUSTRATED WHERE THE ORIGINAL MATCH OF THE FUEL REQUIRED TO MAKE THE REQUIREMENTS WITH THE FUEL WHICH CAN BE MADE AVAILABLE IN A PROPERLY WEIGHT ANALYZED AIRPLANE PRODUCES A FINITE TAKE-OFF GROSS WEIGHT OR AIRPLANE SIZE FOR A WING LOADING OF 60 LB/FT^2 - POINT A. THE CHANGE TO A WING LOADING OF 80 LB/FT^2 PRODUCES A SMALLER AIRPLANE WITH LESS FUEL - POINT B. ALL TRADE PARAMETERS HAVE SUCH AN INFLUENCE AND CAN BE SIMILARLY ENCOMPASSED.

FRC SIZING PROCESS IS USED FOR TRADE-OFFS

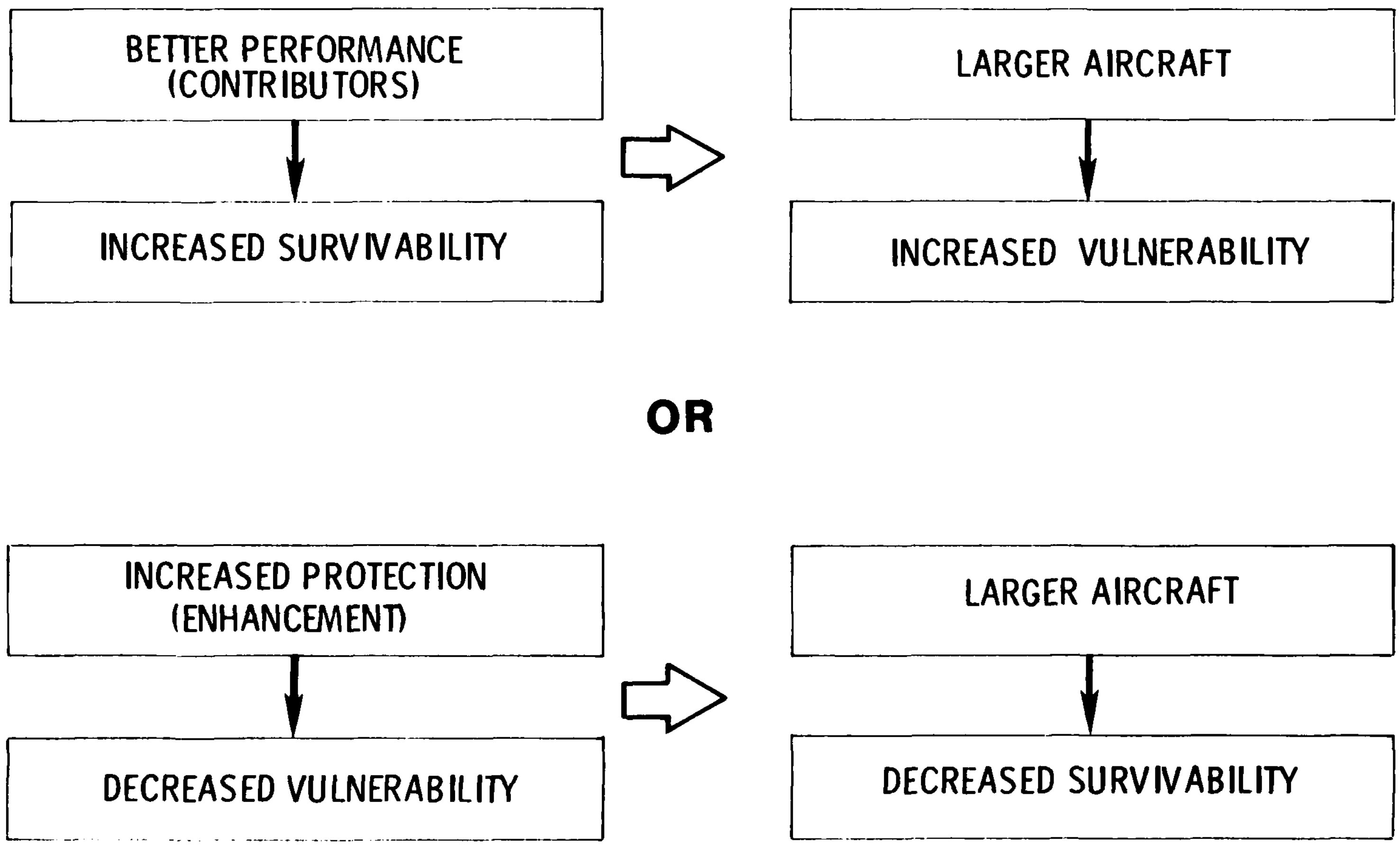


PROCESS CAN HANDLE S/V TRADES

S/V IS NO EXCEPTION. THE PROCESS CAN HANDLE IT IF THE PROPER FORMULATIONS CAN BE INTRODUCED. IT CAN STUDY BETTER PERFORMANCE WHICH YIELDS INCREASED SURVIVABILITY BUT HAVING THE PROPERTY OF CAUSING LARGER AIRCRAFT WITH INCREASED VULNERABILITY VERSUS ENHANCING THESE TO REDUCE VULNERABILITY WHICH ALSO INCREASES SIZE AND REDUCES SURVIVABILITY. ALL COMBINATIONS CAN BE TRADE-STUDIED. THE MISSING METHODOLOGIES FOR ACCOMPLISHING THIS HAVE BEEN DEVELOPED UNDER THE CONTRACT IN A GENERIC, PORTABLE SENSE. SUPPORTING GEOMETRIC AND WEIGHT ANALYSIS METHODOLOGIES ARE INCLUDED.

THE NEXT TWO VU-GRAPHS SHOW TWO EXAMPLES OF HOW THE METHODOLOGY WAS DEVELOPED. THIS IS ILLUSTRATIVE ONLY OF WHAT WAS INCLUDED IN TASK II, THE BULK OF THE CONTRACT WORK.

PROCESS CAN HANDLE S/V TRADES



S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED (CREW SYSTEM)

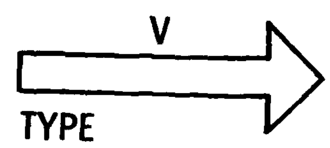
THE CREW STATION VULNERABILITY ASSESSMENT METHODOLOGY FOR AP PROJECTILES WAS DEVELOPED FOR VARIOUS TYPES OF PROJECTILES AND VARYING PROJECTILE VELOCITIES. A 95 PERCENTILE MAN WAS USED. KILL DATA CAME FROM FRC TECHNICAL REPORTS AND VARIES AS SHOWN IN THE GRAPH AT THE LOWER RIGHT.

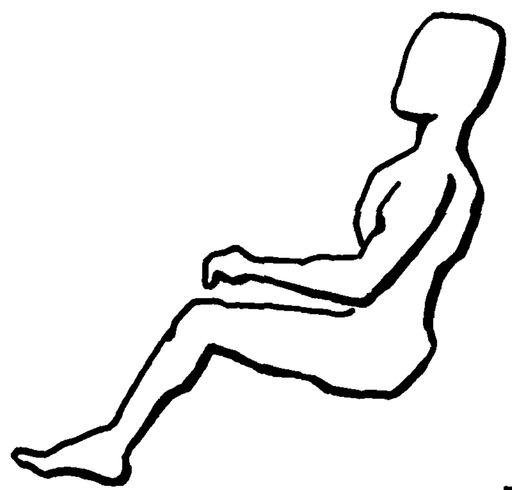
JTCG/AS PENETRATION EQUATIONS DETERMINE THE RESISTANCE TO THE PROJECTILE'S PENETRATION, AND THE STANDARD REDUCED VELOCITY EQUATION, WITH A FACTOR FOR BLUNT PROJECTILES, WAS USED TO DETERMINE THE STRIKING VELOCITY AT THE CREW MEMBER.

FOR THE FUEL SYSTEM, THE FUEL TANKAGE SPECIFICALLY - - - - -

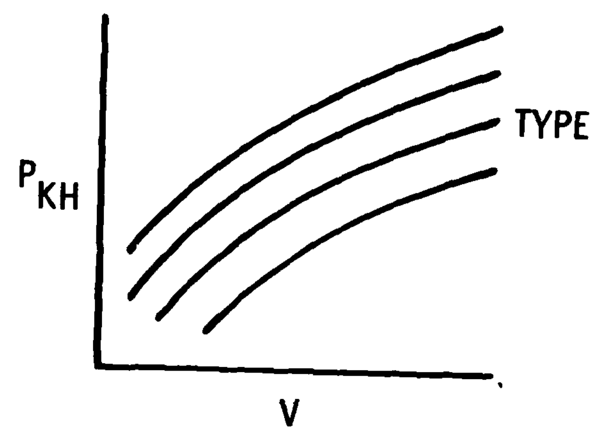
S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED

CRESW SYSTEM





A_P = 95% ILE



- $A_V = P_{KH} \times A_P$
- JTCG/AS PEN. EQUAT'NS
- $V_R^2 = (V_S^2 - V_{50}^2) \times F_{BLUNT}$

S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED (FUEL SYSTEM)

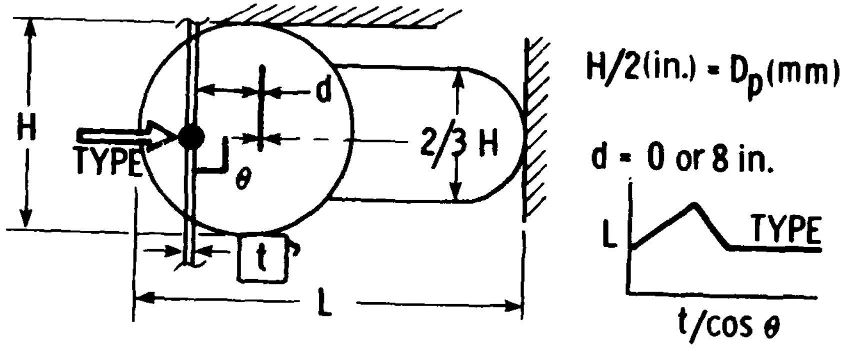
- - - - THE VULNERABILITY ASSESSMENT METHODOLOGY TO A POINT-DETONATING, HIGH-EXPLOSIVE PROJECTILE IS ILLUSTRATED. THE SURFACE SKIN IS AT THE STRIKING POINT AND CONCEPTUAL LOCATIONS OF THE FUEL BOUNDARIES ARE SHOWN IN CROSS-HATCH. THE PENETRATION DEPTH (D) AND THE FIREBALL SHAPE (H AND L) ARE AS DETERMINED IN FRC TECHNICAL REPORTS, FIREBALL DIAMETER H (IN INCHES) AS A FUNCTION OF THE PROJECTILE DIAMETER D_P (IN MM), AND FIREBALL LENGTH AS A FUNCTION OF THE SKIN THICKNESS AND OBLIQUITY. NOT SHOWN, IS A LINEAR DEPENDENCE ON STRIKING VELOCITY.

THIS CASE IS AN UNPROTECTED (I.E., NOT ENHANCED) CASE FOR THE WETTED AREA OF THE FUEL TANKAGE AND FOR AN INTEGRAL OR BLADDER CELL. IT IS ASSUMED THAT THE PROJECTILE FRAGMENTS WILL CAUSE LEAKS AND A FIRE OCCURS ($P_F = 1.0$) IF THE FIREBALL TOUCHES THE LEAKING CELL WALL. IF THE PENETRATION IS INTO THE FUEL CELL, NO FIRE OCCURS ($P_F = 0$).

THE GEOMETRICAL DEVELOPMENTS WHICH ARE PART OF THE METHODOLOGY ARE MEANS OF PREDICTING THE PRESENTED AREA OF THE WETTED FUEL CELL (A_P) AND THE HEIGHT OF THIS REGION (H).

S/V METHODOLOGY FOR CONCEPTUAL DESIGN HAS BEEN DEVELOPED

FUEL SYSTEM



- UNPROTECTED / WETTED – BLADDER
- P_F = 1.0 (INSIDE FUEL = 0)
- REQUIRE $\boxed{A_P}$ WETTED AND WETTED $\boxed{h}$

METHODOLOGY VALIDATED ON A-10A & OV-10A

TASK III OF THE CONTRACT REQUIRED SAMPLE CASES TO BE RUN SO THAT THERE WAS ASSURANCE OF THE WORKABILITY OF THE TASK II METHODOLOGY AND TO DISCOVER ERRORS, OMISSIONS AND IMPROVEMENTS REQUIRED. THE CONTRACTING AGENCY SELECTED THE CASES AND CONDITIONS. VULNERABLE AREA RESULTS FOR BOTH THE A-10A AND OV-10A AIRCRAFT WERE CALCULATED IN THE ENHANCED AND UNENHANCED STATE FOR VARIOUS THREATS. THE WEIGHT INFLUENCES OF ENHANCEMENTS AND THE AIRCRAFT SIZING EFFECTS WERE INCLUDED.

THIS TABLE PROVIDES ONE SET OF RESULTS FOR THE A-10A AIRPLANE. THE "ENHANCED A-10A" COLUMN RESULTS OF THE SAMPLE CASES CAN BE COMPARED TO THE "ACTUAL VALUES" COLUMN WHICH ARE THE A-10A DETAILED ANALYSIS VALUES. EXCEPT WHERE THERE WERE SIGNIFICANT DIFFERENCES IN GROUND RULES IN THE TWO ANALYSES THE AGREEMENT IS QUITE GOOD.

METHODOLOGY VALIDATED ON A-10A & OV-10A

VIEWING ASPECT	THREAT	VELOCITY FT/SEC	VULNERABLE AREAS — SQ. FT.		
			ENHANCED A-10A	UNENHANCED A-10A	ACTUAL VALUES
SIDE	3	1000	1.22	11.32	1.12
		2500	2.94	14.98	2.65
	8	-	6.08	13.20	NOT REQ'D
FRONT	4	1500	2.64	2.95	1.79
TOP	7	1000	189.32	185.58	190.33
BOTTOM	5	1000	76.50*	139.81	1.53*
		2500	18.07*	126.89	1.29*

*A-10A PROGRAM VULNERABILITY GROUND RULES DIFFER FROM CRITERIA EMPLOYED

POSITIVE RESULTS

THE CONTRACTED STUDY HAS DEFINED THE ROLE OF THE S/V ANALYST IN THE CONCEPTUAL DESIGN PROCESS. IT IS SHOWN THAT S/V CAN BE MADE AN INTEGRAL PART OF THE PROCESS BOTH BY INFLUENCING THE SIZING ASPECTS AND BY INCLUSION IN THE TRADE-STUDY ASPECTS. A METHODOLOGY HAS BEEN DEVELOPED WHICH CAN SERVE AS A GENERIC MODEL AND IT INCORPORATES THE NECESSARY GEOMETRICAL/WEIGHT PREDICTION DEVELOPMENTS. THE METHODOLOGY IS COMPLEX AND REQUIRES COMPUTERIZATION.

IT WAS ALSO NOTED IN THE STUDY THAT THE GRAPHICS CAPABILITIES INHERENT IN CURRENT CAD/CAM AND ICAD DEVELOPMENTS ADD A NEW DIMENSION TO THE PROBLEM OF INCORPORATING S/V IN THE CONCEPTUAL DESIGN PROCESS. THEORETICAL FORMULATIONS WILL BE REPLACED BY MEASUREABLE, PICTORIAL REPRESENTATIONS.

POSITIVE RESULTS

- S/V CAN BE INCORPORATED
  - SIZING
  - TRADE STUDY
- METHODOLOGY AS MODEL
- DEFINITIVE GEOMETRICAL DEVELOPMENTS
- COMPLEX/COMPUTERIZE
- CAD/ICAD ADDS NEW DIMENSION

DA

FILM

5